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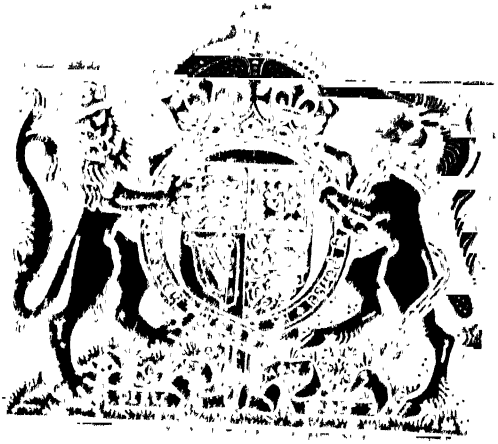

IMPERIAL AGRICULTURAL
RESEARCH INSTITUTE, NEW DELHI.

Proceedings of the Twenty-fifth Indian Science Congress

PART II—PRESIDENTIAL ADDRESSES

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Inaugural Address

Congress President :—SIR JAMES JEANS, D.Sc., Sc.D., LL.D., F.R.S.

Until a very few weeks ago, we had hoped to assemble here under the Presidency of one of the greatest scientists of all time, and it is inevitable that his sudden and tragic death should be uppermost, not only in the thoughts of those of us who come from Europe, most of whom knew him personally, but in the thoughts of everyone here. For his works had made him known to us all. He has been cut off in the fulness of his powers —leaving as his monument a rich and full life's work, such as few men have equalled, but also leaving a feeling that he might have accomplished more, and possibly even greater, things had he been left with us a few years longer.

Those of us who were honoured by his friendship know that his greatness as a scientist was matched by his greatness as a man. We remember, and always shall remember, with affection his big, energetic, exuberant personality, the simplicity, sincerity and transparent honesty of his character, and, perhaps most of all, his genius for friendship and good comradeship. Honours of every conceivable kind had been showered upon him, so that he could not but know of the esteem in which he was held by the whole world, and yet was always simple, unassuming and ready to listen patiently to even the youngest and most inexperienced of his pupils or fellow-workers, if only he were honestly seeking for scientific truth.

This is neither the place nor the occasion to attempt any detailed description of his scientific achievements. A great physicist, Niels Bohr—whom we are sorry not to have with us here—speaking of Rutherford's work to a congress of physicists which recently met in Bologna, said : ' His achievements are so great that, at a gathering of physicists like the one here assembled, they provide the background of almost every word that is spoken '. As it was in Bologna, so it will be in Calcutta ; the proceedings in our physics section will be utterly different from what they would have been had Rutherford not lived and worked. And it is sad to think that they will be utterly different from what they would have been had he lived even a few months longer, for then we should have had his ardent and inspiring personality and vast fund of knowledge and experience to direct and enliven our debates. Happily he will not be altogether absent from our meeting. He had been looking forward with the greatest interest and eagerness to this occasion, and had already written a Presidential address for it, which it will be my duty to read to you very shortly.

In this he tells us, in his own words, of his latest work of all—that in nuclear physics, and especially in what he described as 'the new alchemy', the transmutation of the elements. This alone would have ensured him a place in the foremost rank of physicists, and yet it formed only a small part of the total achievement of his life.

When I first knew him, almost exactly forty years ago, he was experimenting in wireless telegraphy, using a detector of his own invention, and transmitting signals to what was, for those times, the record distance of about a mile and a half.

That was in the period which he used himself to describe as 'the heroic age of physics'. Within the space of a very few years, Röntgen rays were discovered and provided a new line of attack on the problems of electric conduction in gases; the electron was isolated, and seemed to point the way to an understanding of the age-long puzzle of the structure of matter; radio-activity was discovered, with its apparent violation of well-established physical laws, and opened up a new road which led no one knew where—but obviously into very different territory from that which nineteenth century physics had so industriously and thoroughly explored.

Rutherford directed his colossal energy and tireless enthusiasm on to all these vast new problems in turn. By a few investigations of masterly simplicity, he reduced the puzzling phenomena of radio-activity to law and order, and, in collaboration with Soddy, discovered the physical interpretation of this law and order. Radio-activity, they found, indicated the transmutation of one element into others through processes of spontaneous atomic explosion.

Rutherford then treated the α-particles which were emitted at these radio-active explosions as projectiles. He bombarded atoms with them and in so doing discovered the composition of the atoms. Finally he shewed how similar bombardments could change the constitution of the atomic nuclei, and so literally transmute the elements; the dream of the alchemists was realized.

These were perhaps the outstanding landmarks in his career, but in truth most of his investigations were key investigations, each brilliant in its simplicity of conception, masterly in its execution and far-reaching in its consequences. His output of work was enormous and can only be explained by his capacity for delegating all the less important details of an investigation to a collaborator, whom he usually inspired with his own enthusiasm. In his flair for the right line of approach to a problem, as well as in the simple directness of his methods of attack, he often reminds us of Faraday, but he had two great advantages which Faraday did not possess—first, exuberant bodily health and energy, and second, the opportunity and capacity to direct a band of enthusiastic co-workers. Great though Faraday's output of work was, it seems to me that to match Rutherford's work in quantity as well as in quality, we must go back to Newton.

Voltaire once said that Newton was more fortunate than any other scientist could ever be, since it could fall to only one man to discover the laws which governed the universe. Had he lived in a later age, he might have said something similar of Rutherford and the realm of the infinitely small; for Rutherford was the Newton of atomic physics. In some respects he was more fortunate than Newton: there was nothing in Rutherford's life to compare with the years which Newton spent in a vain search for the philosopher's stone, or with Newton's output of misleading optical theories, or with his bitter quarrels with his contemporaries. Rutherford was ever the happy warrior—happy in his work, happy in its outcome, and happy in its human contacts.

Through the tragic circumstance of his death, I stand before you as your President. I cannot tell you how greatly honoured I feel by your choice, but neither can I tell you how strongly I feel my utter inadequacy to act as substitute for the really great man we had all hoped to have with us here.

Yet I must not forget that I am here in a second capacity also—as spokesman of the Delegation from the British Association. It so happened that I was President of the Association in 1934, when we received your invitation to join you in Calcutta, and I vividly remember how anxious your representatives were to do everything possible to make our visit not only scientifically fruitful, but also pleasurable to ourselves.

I am sure I speak for the whole of the European deputation in thanking you once again for your lavish and carefully-planned hospitality.

To some of us—but only a few—India is well-known territory; others—I think the majority—come here for the first time. But we all feel a special interest in being here for the 25th Anniversary of your Indian Association. The quarter-century of your existence has been a period of stupendous developments in almost all branches of science, and certainly not least in those which have formed my own field of work. Twenty-five years ago the astronomers were still debating as to whether the great spiral nebulæ were inside the galactic system or outside; estimates of the distances of these nebulæ differed by factors of at least 100, and the vast universe of extra-galactic astronomy was still closed territory. The genius of Einstein had already given us the restricted theory of relativity—the simple physical theory which grew out of the Michelson-Morley experiment—but the more complex gravitational theory was still unborn, and we were still perplexed by its puzzles as to whether the universe was finite or infinite, and whether space and time were real or unreal. In physics, Planck had given us the rudimentary quantum-theory which was required by the phenomena of black-body radiation, but its application to atomic physics was yet to come. Rutherford's epoch-making investigation on the scattering of α-particles by atoms had just, but only just, shewn us the atom as we see it today—the heavy nucleus with the cloud of light electrons surrounding it. Bohr immediately seized upon this concept and developed it further; he shewed how the quantum theory could be applied to the movements of this cloud of electrons, and made it yield an interpretation of atomic spectra. On this basis were built first the old quantum-theory and then the far vaster structures of the new quantum-theory and the wave-mechanics. Finally the new science of nuclear physics came into being, largely as a personal creation of Rutherford; his very last utterance on this subject was written especially for you, and in a few minutes I shall be reading it to you.

Nor has India stood idly by as a mere spectator of this most thrilling period in the history of science. These twenty-five years have not only seen your association increase from infinitesimal beginnings to its present international importance; they have also seen the phenomenal growth of India as a scientific nation. In 1911 there were no Indian-born fellows of the Royal Society; to-day there are four. In 1911 the Royal Society published no papers by Indians, in 1936 we published ten. Yet statistics are dry things, and even those which shew an infinity-fold increase convey a less vivid picture than a few concrete examples, such as each of us can find in abundance in his own subject. The mathematicians and physicists will probably find their thoughts turning, as mine do, to the strangely intuitive genius of Ramanujan and to the remarkable discoveries he had made in pure mathematics before death snatched him prematurely away: to the work of Sir Venkata Raman in physics, and especially his discovery of the effect which is known by his name all the world over; to many investigations in sound and the theory of music made by Raman and a host of others; to the work of Saha in astrophysics, which gave us our first clear understanding of the meaning of stellar spectra, and so unlocked the road to vast new fields of astronomical knowledge; and to the work of many Indians, among whom I would specially mention Chandrasekhar and Kothari, on conditions in the interiors of the stars. And I am sure that not only the mathematicians and physicists, but workers in all other fields as well, will be thinking with admiration of the remarkable ingenuity and experimental skill shewn by that great Indian scientist, the late Sir Jagadis Chunder Bose.

If such names and achievements as these come into the mind of a worker in one only of the many vast fields of science, we can form some slight idea of the richness of India's contribution to science as a whole. Thinking on this great contribution, we of the British Association congratulate you of the Sister Association most whole-heartedly, not only on the completion of your twenty-five years of existence, but even more on the wealth of harvest you have gathered in that twenty-five years.

Presidential Address[1]

Congress President-Elect :—

PROF. THE RT. HON. LORD RUTHERFORD OF NELSON,
O.M., F.R.S., D.SC., LL.D., PH.D.

During the past fifty years, the British Association for the Advancement of Science has been invited on many occasions to hold its meetings overseas. Four times it has journeyed to Canada (Montreal 1884, Toronto 1897, Winnipeg 1909, Toronto 1924), twice to South Africa (1905, 1929), once to Australia (1914). This policy of the Association of arranging occasional meetings in our Dominions has proved an unqualified success. These overseas visits have had a marked influence on the progress of science throughout our Commonwealth and by personal contacts have helped much to promote mutual understanding and co-operation between our peoples.

The visit of a representative group of scientific men to our most distant Dominions in 1914, in itself an outstanding event in the history of the Association, was rendered even more notable by the dramatic circumstances under which the meetings were held, for the arrival of the party in Australia coincided with the news of the outbreak of the Great War. No one who like myself took part in the meetings in Australia and New Zealand in those troubled but stirring times can ever forget the warmth of our reception. We were privileged to witness that wonderful response of the peoples of these lands to the call of danger—a response which we know grew ever greater with the need.

It has long been the wish of the British Association to hold a meeting in India, but difficulties of time and climate have stood in the way of its realization. It has been found most convenient for the overseas visits to take place in the summer months but such a time is quite unsuitable for India. This difficulty would be in part surmounted if a representative party of scientific men could obtain leave of absence from their duties to visit India during the cold weather.

The celebration of the Silver Jubilee of the founding of the Indian Science Congress Association offered a suitable occasion for such a visit, and arrangements have been made by the two Associations to hold a joint meeting in India. I gladly accepted the invitation of the two bodies to preside over this combined meeting. I feel it not only a great honour but a great privilege and responsibility to be asked to fill this post on such an historic occasion. This visit of the British Association to your shores is a symbol of our desire to extend the hand of greeting and fellowship to our sister society and also individually to our co-workers in science in India.

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[1] Received after Lord Rutherford's death.

While science has no politics, I am sure it is of good omen that our visit happens to fall at a time when India is entering upon a new and important era of responsible co-operative government in the success of which both our countries are deeply concerned.

On behalf of the British Association, I extend to the Indian Association our warmest congratulations on this the twenty-fifth anniversary of its foundation and our sincere wishes for its continued success. We recognize that your Association, both in its constitution and its aims so closely resembling the British Association, has proved of great service to the progress of science throughout India. Founded at a time when the Universities were becoming centres of original research, it afforded to a widely scattered scientific community a much needed common meeting ground for the discussion of scientific problems. It helped also to bring to the attention of the interested public the importance of science and of the scientific method in national development. I think it can be safely stated that the success of the meetings of the Indian Association in no small degree influenced the later foundation of specialist societies in India, for example, the Chemical Society and Physics Society.

On such an occasion as this, we must not forget to do honour to those who were largely instrumental in founding your Association and in guiding its infant steps. I would refer in particular to Professor J. L. Simonsen, Professor P. S. MacMahon and your senior Past-President, Sir Sydney Burrard. The Association owed much in its early days to the friendly support and encouragement so freely given by that premier Indian Society, the Royal Asiatic Society of Bengal of which I am proud to be an honorary Fellow.

In earlier days in India, research was largely confined to the great official scientific services, initiated and maintained on a generous scale by the Indian Government, for example, the Survey of India, the Geological Survey, the Botanical Survey, the Departments of Agriculture and Meteorology and many others. Pioneer work of outstanding scientific importance has been done by all these services. In the short time at my disposal, I can only make a passing reference to a few items of work accomplished, and can mention only a few of the array of distinguished names which have been connected with these great scientific services.

The Trigonometrical Survey of India has a long and distinguished history. The splendid series of geodetic measurements along an arc from Cape Comorin to the Himalayas, made by

Everest, was of outstanding importance and his name is for ever associated with the highest peak in the world. As a result of this survey, the deflections of a plumb line, due to the gravitational attraction of the Himalayan range, were determined at different points. A careful comparison of the results of observation with calculation, largely due to the work of Archdeacon Pratt of Calcutta, and later of Sir Sydney Burrard, disclosed marked discrepancies, the effect of the mountain mass at a distance being much less than was expected. Attempts to explain these and other anomalies ultimately led to the formulation of a new and important theory of mountain formation known as the principle of isostasy. On this hypothesis, the excess pressure due to a mountain mass is compensated for by a deficiency of matter below its base. This conclusion, which is in accord with extensive gravitational as well as geodetic measurements in India, is believed to be of general application to mountain formation throughout the world.

I may recall that a former distinguished Superintendent of this Survey, Sir Gerald Lenox Conyngham, is now Head of the Department of Geodesy in Cambridge.

The Geological Survey, one of the oldest scientific services in India, has a fine record of work accomplished and its survey of the mineral resources of India has proved of great value to Indian industry. Among many distinguished names, I may specially mention that of Sir Thomas Holland, a former Director, who has done such good work for your country in peace and war. I believe that it was largely due to his energy and scientific insight that the great Tata Iron and Steel Works were begun.

The Department of Meteorology has done much pioneering research and was one of the first to realize the importance of studying the conditions of the upper air by means of small balloons—a subject of ever-increasing importance with the advent of the aeroplane. I have always felt a friendly interest in this Department as many of its members are known to me personally. Amongst them is Sir Gilbert Walker, a former Director and once President of this Association, who did much to improve the Meteorological Service in India and himself made important original contributions to our knowledge of the South-West Monsoon. I may recall that the present distinguished head of the Meteorological Office of Great Britain, Sir George Simpson, was for many years a member of this Indian Department.

The study of the botanical riches of India owes much to the work of Roxburgh, Wallich and Prain, and also that explorer and naturalist, Hooker, whose work on the flora of British India is known to you all.

In Forestry, India has at Dehra Dun probably the finest research laboratory of its kind in the world. We in England owe a debt of gratitude to India in providing us with our distinguished Professor of Forestry at Oxford, Professor R. S. Troup, and the first two directors of our Forest Products Laboratory, namely Sir Ralph Pearson and Mr. W. A. Robertson.

While in this brief survey I can mention only a few departments out of many, yet I must not omit to refer to the great advances in knowledge due to the Indian Medical Service, so well represented by the pioneer work of Ross on malaria and by Leonard Rogers on cholera and leprosy, researches which gave new hope to the peoples of India.

In the early days of the Indian Universities, attention was mainly directed to teaching and examining the large number of students who presented themselves, and comparatively little attention was paid to research. There were always a few, however, who recognized that the universities had a wider part to play in Indian education, and should become centres of research as well as of teaching. Amongst those pioneers who distinguished themselves by original investigations and by the stimulation of others, I should particularly mention Sir Alexander Pedler, Sir Alfred Bourne, Sir Jagadis Bose and Sir Prafulla Ray, and it is of interest to recall that the last three have all been presidents of your Association.

As a result of the Curzon Commission on Education in 1904, many of the universities introduced honours courses, and by new appointments and improvements in laboratories stimulated research in science. Excellent well-equipped schools of research have arisen in many Indian universities, where good opportunities are available for the training of potential investigators in the methods of research. The Indian student has shown his capacity as an original investigator in many fields of science, and, in consequence, India is now taking an honourable part and an ever-increasing share in the advance of knowledge in pure science.

Amongst many workers of distinction, I may specially mention Sir Venkata Raman, Professor M. N. Saha and Professor B. Sahni, each of whom has made outstanding contributions. That premier scientific society of Great Britain, the Royal Society, has recognized the value of their work by election to its Fellowship.

We in Great Britain watch with pride this growth of the scientific spirit in India and are pleased to help in any way we can. As an example of our interest, I may recall that Trinity College, Cambridge—my own college—assisted that mathematical genius Ramanujan to prosecute his studies in Cambridge. He was soon elected a Fellow of that College and a Fellow of the Royal Society. But for his premature death, it may be said of him, as Newton said of Cotes, that we had known something.

The researches in astrophysics of S. Chandrasekhar in Cambridge were soon recognized by the award to him of an Isaac Newton Studentship and later by his election to a Fellowship in Trinity College.

As a member of the Royal Commission for the Exhibition of 1851, I would like to refer to some events this year of special interest to India. This Commission awards each year a number of Overseas Scholarships to our Dominions, as well as Senior Research Studentships open to competition in England by all members of our Commonwealth. The opportunity offered by these scholarships to promising investigators from overseas to continue their work in England or abroad has proved of great value to the progress of science. I am proud to remember that I myself was awarded an 1851 Scholarship on the recommendation of the University of New Zealand.

It has for some time been the wish of the 1851 Commission to be able to offer one or more of its Overseas Scholarships for award to students in India. Owing to difficulties of finance, it was only this year that this project was realized. A preliminary committee of selection was set up in India and the Commissioners with whom lay the final choice have appointed Mr. N. S. Nagendra Nath of the Indian Institute of Science, Bangalore, as the first 1851 Exhibition Scholar from India. He will proceed to Cambridge to carry out investigations in Theoretical Physics. For the first time also, an Indian student in Cambridge, Dr. H. J. Bhabha, has been awarded in open competition one of our valuable Senior 1851 Studentships in recognition of the importance of his researches in Theoretical Physics. The Commission would like to be in a position to allot a second Science Scholarship to India but funds are insufficient. The machinery, however, is there, and I know that the Commissioners would be only too happy to administer a second award if anyone in India, who is interested in her scientific progress, were generous enough to provide the necessary endowment.

While, as we have seen, the universities of India have in later years made substantial progress both in teaching and research in science, yet it must be borne in mind that still greater responsibilities are likely to fall on them in the near future. This is in a sense a scientific age, where there is an ever-increasing recognition throughout the world of the importance of science to national development. A number of great nations are now expending large sums in financing scientific and industrial research with a view to using their natural resources to the best advantages. Much attention is also paid to the improvement of industrial processes and also to conducting researches in pure science which it is hoped may ultimately lead to the rise of new industries.

It is natural to look to the universities and technical institutions for the selection and training of the scientific men required for this development. In India, as in many other countries, there is likely to be a greater demand in the near future for well-trained scientific men. With the growth of responsible government in India, it is to be anticipated that the staff required for the scientific services in India and for industrial research will more and more be drawn from students trained in the Indian universities. It is thus imperative that the universities should be in a position not only to give a sound theoretical and practical instruction in the various branches of science but, what is more difficult, to select from the main body of scientific students those who are to be trained in the methods of research. It is from this relatively small group that we may expect to obtain the future leaders of research both for the Universities and for general research organizations. This is a case where quality is more important than quantity, for experience has shown that the progress of science depends in no small degree on the emergence of men of outstanding originality of mind who are endowed with a natural capacity for scientific investigation and for stimulating and directing the work of others along fruitful lines. Leaders of this type are rare but are essential for the success of any research organization. With inefficient leadership, it is as fatally easy to waste money in applied research as in other branches of human activity.

The selection of such potential investigators and leaders is not an easy task, for success in examinations in science is no certain criterion that the student is fitted for a research career. A preliminary training in research methods for a year or two is required to select those who possess the requisite qualities of originality and aptitude for investigation. A system of grants-in-aid or scholarships to approved students may be required for such postgraduate training. In Great Britain the financial help given by the Universities and other educational institutions for training in research is in many cases supplemented by maintenance grants to promising students, awarded by the Department of Scientific and Industrial Research. This system has proved of much value both in developing the research activities of the universities and in providing a supply of competent men both for research in pure science and in industry.

I have so far mentioned some aspects of the scientific work carried out by the universities and government services of India. I am well aware that much attention has also been directed to the need of scientific research in agriculture, and in certain industries. An Indian Cotton Committee has been set up which has given admirable service, while the Indian Lac Cess Committee arranges for investigations in that unique Indian product, some of which are carried out in Great Britain. I am interested to know that an Agricultural Research Council has recently been formed, largely as a result of the findings of a Commission of which His Excellency the Viceroy was Chairman.

While I cannot lay claim to have any first-hand knowledge of Indian industries and conditions, yet perhaps I may be allowed to make some general observations on the importance in the national interest of a planned scheme of research in applied science. If India is determined to do all she can to raise the standards of the life and health of her peoples and to hold her own in the markets of the world, more and more use must be made of the help that science can give. Science can help her to make the best use of her material resources of all kinds, and to ensure that her industries are run on the most efficient lines. National research requires national planning. If research is to be directed in the most useful direction, it is just as important for a nation as for a private firm to decide what it wishes to make and sell. It is clear also that any system of organized research must have regard to the economic structure of the country. One essential fact at once stands out. India is mainly an agricultural country, for more than three-quarters of her people gain their living from the land, while not more than three per cent. are supported by any single industry. A glance at the official review of the trade of India shows that the annual production of wheat has risen since 1914 from about 8·3 to 9·5 million tons, while exports in the same period have fallen from over a million tons to 10,000 tons. In the case of another important food, rice, the Indian production, exclusive of Burma, has remained fairly steady, varying between 22 and 25 million tons annually, but here also exports have fallen from about half a million tons before the War to about 200,000 tons.

In view of these facts, it would seem clear that, in any national scheme of research, research on foodstuffs has a primary claim on India's attention. Quite apart from improvements in the systems of agriculture used in India, there is a vast field for the application of scientific knowledge to the improvement of crops, for example, by seeking for improved strains suitable for local conditions, by research on fertilizers and in many other directions. The fact that surplus wheat for export has decreased suggests that the present production is required for home consumption in India. When the permanent schemes of irrigation now in hand bring much more land under full cultivation, India may again wish to take her place in the export market. To do this in the face of international competition, well-planned agricultural research will be essential.

While the character of India's trade has seen many changes in the last hundred years, to-day exports of cotton, jute and tea amount to about 60 per cent. of the total exports of India. Next in importance come oil and seeds 6 per cent., hides 5 per cent. and lac 1 per cent. There is no doubt that more scientific knowledge would increase the production of all these products. There is of course the need to make sure that there is a market for such a surplus. Of India's standard exports, cotton represents about 20 per cent. of the total value. In spite of recent strenuous attempts to improve Indian cotton, its staple is still usually looked upon in the world's markets as short and coarse. No doubt there are purposes for which cotton of this type possesses special advantages, though the demand for it must now be very near to saturation point. Still, India only produces about 16 per cent. of the world's cotton crops and there appears to be no reason why it should not produce a larger share; but until the cultivation of better varieties is more extensive, competition with cottons of the American type in the world markets will certainly be difficult. Here there appears to be a wide field for applied research. Good work has been done by the Indian Cotton Committee which has taken steps to improve the staple and prevent adulteration and inter-mixture of various varieties. The problem can be approached, however, not only in the seeking of better varieties but in finding uses and methods of treatment for the short staple variety. The importance of research on the cotton itself is well brought home by the results achieved in the United Kingdom, where the British Cotton Industry Research Association at the Shirley Institute has found that many of the defects which appear in the finished article can be traced back to defects in the raw material.

Finally a word might be said concerning the need for research on radio-communication, so important a matter to a large country like India. I do not refer to technical research in transmitting and receiving apparatus, but rather to the type of fundamental investigation pursued under the Radio Research Board in Great Britain. These investigations, begun in the early days after the War, have shown that the propagation of radio-waves over large distances is very sensitive to the electrical state of the upper atmosphere. It is now established that a number of electrified layers exist in the higher atmosphere which under certain conditions are able to reflect electric waves. The details of this electrical distribution vary considerably with the hour of the day and with the season of the year, as well as with geographical location. Such information, which is of practical importance in the selection of the most suitable wave-lengths for radio-communication, must obviously be secured by research conducted in the country itself. Moreover, it does not seem impossible that such a survey may prove of value in long range weather forecasting.

There is here, then, much scope for research in a wide field, which I hope will be pursued vigorously in India. It is pleasant to note that a most promising beginning in tackling fundamental radio problems of this character has already been made here by Professors M. N. Saha and S. K. Mitra and their students. The importance of survey work of this kind has already been recognized in other parts of the Empire, where it has received official support and encouragement. I will refer in particular to the admirable work in this field by the Radio Research Board of Australia.

Industrial Research in Great Britain.

While I recognize the great differences which exist between the industrial and agricultural conditions in Great Britain and India, yet it may prove of some interest and, I hope, of some value, if I give a brief account of some of the ways in which the British Government has aided industrial and agricultural research in the period following the Great War. From the dawn of the scientific age, Great Britain has taken a prominent place in advancing knowledge both in pure research in our universities and in applied research for the development of industry. Before the War, progress in industry depended in the main on the brilliant contributions of individual workers rather than on any systematic attack by scientific methods on the problems of industry. We may instance the pioneer work of Bessemer for the steel industry and of Parsons in the development of the steam-turbine which had such a great effect on the power-industry. One cannot pay too high a tribute to the greatness of the achievements of individual inventors and investigators such as these, for it was largely due to them that Great Britain obtained so great an industrial position in the last century.

Yet I think it is true to say that in the period before the War the country as a whole failed to recognize as fully as some other nations the importance of an organized scientific attack on broad lines on the problems of industry. In a number of cases, British science gave ideas to the world, but it was left to other nations to develop them by intensive research and to reap the industrial benefit.

This weakness in our organization became apparent in the War when the production of munitions and materials threw a great strain on industry. The common danger brought the industrialist and man of science into close co-operation to their mutual benefit. The results of this co-operation surpassed all expectation. New chemical processes were evolved, many new devices arose, while communications were revolutionized by the rapid development of the thermionic valve. In a hundred different ways, the co-operation of science with industry had justified itself by its success.

Early in the War, the British Government recognized that when peace came, a more systematic application of science and research over a broader field was essential in the national interest and, amid the distractions of war, set up the necessary machinery to accomplish this. In 1915 the Department of Scientific and Industrial Research was formed, and a few years later in 1920 the Medical Research Council was set up to undertake investigations in all matters connected with the health of the people. This was followed in 1931 by the formation of the Agricultural Research Council. The formation of the Department of Scientific and Industrial Research marked the first comprehensive and organized measure taken in Great Britain to help industry generally through the application of science. A number of new research organizations were set up, controlled and financed by the Department, to deal with the scientific aspects of the use of fuel, of the storage and transport of food, of buildings and later of roads—subjects of great importance to the common welfare of the people but on which little if any organized research had been undertaken.

Coal is the greatest material asset possessed by Great Britain, for on it mainly depends the heating of our homes and the production of power for most industries. Its better utilisation is a problem of great national importance. To achieve this purpose, the Fuel Research Board was formed and a large laboratory was erected at Greenwich to carry out investigations on the better and more economic use of coal. An important section of this work is a national survey of the coal resources of Great Britain carried out in special laboratories in the several coalfields. The properties of the coal in the various seams are carefully examined and, if necessary, full scale trials are made at the Fuel Research Station to test the suitability of the coal, for example, for carbonization, for steam raising or for conversion into oil. The results of this survey, which is still in progress, have proved of increasing value not only to the colliery owner and the industrialist but also for the needs of the export trade.

In Great Britain every year upwards of 100 million pounds are spent on the erection of new buildings and in maintaining old ones, yet no organized research on buildings had been made. To remedy this deficiency, the Department set up a Building Research Station near London where investigations are made on the many and varied problems connected with the better housing of the people. For example, investigations are carried out to find a scientific explanation of the traditional practices which have grown up in the building trade, for on this depends a rational adjustment of materials and methods to meet modern needs. The results of such a scientific enquiry in this comparatively unexplored field cannot fail to have a marked influence on building construction generally.

The Building Research Station embraces in its programme all problems connected with building materials except those associated with the use of timber. These are dealt with at another establishment of the Department, the Forest Products Research Laboratory. Here intensive researches are carried out on the best use of timber and its preservation. The country spends large sums annually on timber, much of it imported, and in the national interest it is of great importance to us that the best value is obtained for this outlay.

You are all aware that food represents one of Great Britain's largest imports, and much of this is transported great distances from overseas. An organization was set up known as the Food

Investigation Board, to consider the best methods of storage and transport of food, so as to avoid waste and loss of nutritive value. Much of this work has its centre at the Low Temperature Research Station in Cambridge, but a special station at Torry, Aberdeen, deals with the preservation of fish and another at Ditton in Kent with the storage of fruit. Investigations in this field, which owe so much to the initiative of the late Sir William Hardy, have proved very valuable in many directions, and have led to great improvements in the conditions of transport and storage of a great variety of food stuffs.

I may give one example out of many of the striking consequences of such researches. The Low Temperature Research Station found that beef in a chilled state could be safely stored for 60 or 70 days in a suitable atmosphere of carbon dioxide. The importance of this discovery, which enabled beef to be carried in first rate condition from our most distant Dominions, was at once recognized by the interests concerned. The first shipment of chilled beef carried by this new method of gas storage was landed in 1929 from New Zealand. Since that time, shipments from Australasia have steadily increased, and most of the vessels built for the Australasian trade have now chambers specially constructed for transport in gas storage.

While the development of our roads in the past owes much to the pioneer work of men like Macadam and Telford, there was no planned organization to add to our knowledge of road construction until comparatively recent years, when the Road Research Station was set up at Harmondsworth near Slough to deal with problems of road construction and the study of road wear under modern conditions of traffic. When we consider the large sums spent every year on the construction and maintenance of roads, the need of such scientific investigation is obvious.

The group of research organizations so far considered deals with the primary needs and interests of the people as a whole as regards food, fuel, building and roads. No independent establishment was set up to deal with another important need of the people, namely clothes, for this is most appropriately provided for by the large research associations which have been instituted in connection with the cotton, wool, and linen industries.

Of the national organizations under the charge of the Department, the largest and probably the most important is the National Physical Laboratory at Teddington, which covers about 50 acres and employs a staff of nearly 700 persons. The work of this Laboratory, primarily intended for the assistance of industry in general, covers a very wide field. It has eight great departments devoted to the study of the different branches of Physics, Electrotechnics, Engineering, Metallurgy and Metrology, Radio-communications, Aero-dynamics and the investigation of ship design. The Laboratory is responsible for the maintenance of the

National Standards and for refined measurements connected with them. It is not always realized to what a great extent modern mass production depends on the maintenance of exact standards and the Laboratory plays an important part in testing the accuracy of gauges so necessary in modern industry.

In 1925 a Chemical Research Laboratory was set up at Teddington, in which pioneer work is being carried out on chemical reactions at high pressures and temperatures and in the production of synthetic resins. Another important problem in which the Department is interested is the provision of more plentiful supplies of pure water for domestic and industrial consumption. Valuable work has been done by the Water Pollution Research Board in many directions, and new methods have been found for the purification of water which has been contaminated by the industrial effluents from sugar and milk factories.

I have so far mentioned research organizations which have been set up to encourage the application of science to problems which affect the daily life of the people and the nation's industries considered as a whole. I should mention that these national organizations to which I have referred are not only willing but anxious to co-operate with corresponding institutions which may be set up in India or the Dominions.

I must now refer to arrangements which have been made to promote the application of scientific knowledge to the problems of the individual industries. The importance of research has long been recognized by large industrial companies, who have in many cases set up research establishments for their own requirements. This tendency is specially marked in the electrical and chemical industries, where large sums are spent annually on research.

It is, however, to be borne in mind that a great part of British industry is carried out in small establishments. A survey carried out some years ago indicated that in 128,000 factories in Great Britain less than 500 employed more than 1,000 workers while over 117,000 employed less than 100 workers. Obviously such small factories are not in a position to maintain a research laboratory on anything but a small and inefficient scale. To overcome this difficulty, the Department in conjunction with industry instituted a number of co-operative research associations representing the greater part of the main industries of the country. Each of these research associations is autonomous and controlled by representatives of the industry concerned, and is financed by contributions from the firms belonging to the association, assisted by grants from the Department.

This bold experiment in the co-operative organization of research, which is unique in the world, has undoubtedly proved a great success. To-day there are twenty such research associations formed on a national basis in their respective industries and for membership of which all British firms are eligible. They cover the metal and textile industries, paint, leather, boots and shoes, rubber, flour milling, cocoa and confectionery, food, printing, scientific instruments and the automobile and electrical industries. From small beginnings, a number of these associations have steadily grown in size and strength until they now form an indispensable and valuable part of the industries they represent.

I can speak with some knowledge of the marked progress made by these two types of research organization, as I have been privileged, as Chairman of the Advisory Council of the Department of Scientific and Industrial Research for the past 8 years, to come in close contact with them. While much still remains to be accomplished, there has been a great advance in recent years in the recognition of the value of research in increasing the efficiency of industry. If we are to hold our own in face of the ever increasing competition in the world to-day, it is essential that our industries should take full advantage of the resources which science places at their disposal.

It is of interest to note that the Overseas Dominions have not been slow to appreciate the importance of such national organizations in the development of their national resources and industries. Healthy research organizations under the control of National Research Councils or corresponding bodies have been set up in Canada, Australia, New Zealand and South Africa. Both in Canada and Australia, which have a Federal system of Government, the research organization is national in the true sense of the word, and responsible only to the central Government.

It is to be borne in mind that the organization of research for industry and for general national purposes varies much in different countries. A research organization which may prove adequate for a country like Great Britain may prove quite unsuitable for another country with different needs and different industrial conditions. In developing any organized scheme of research, each country must consider its own resources and its own particular requirements. As we have seen, the organization of research not only in Great Britain but in the Dominions, is national in scope. Even in a large country like India, where the resources and needs of the different Provinces are very varied, it seems to me essential for efficiency that the organization of research should be on national rather than on provincial lines. The setting up of separate research establishments for similar purposes in the various provinces cannot but lead to much overlapping of work and waste of effort and money. Such a central organization of research does not necessarily mean that the scientific work should all be concentrated in a single laboratory. For example, I understand that a single organization is responsible for the research in cotton for the whole of India. While the more fundamental research is done at a conveniently situated laboratory, much of the work of a special character is carried out in the provinces where cotton is grown.

In Great Britain, the responsibility for planning the programmes of research, even when the cost is borne directly by the Government, rests with research councils or committees who are not themselves State servants but distinguished representatives of pure science and industry. It is to be hoped that if any comparable organization is developed in India, there will be a proper representation of scientific men from the universities and corresponding institutions and also of the industries directly concerned. It is of the highest importance that the detailed planning of research should be left entirely in the hands of those who have the requisite specialized knowledge of the problems which require attack. In the British organizations there is no political atmosphere, but of course the responsibility for allocating the necessary funds ultimately rests with the Government.

In this address, I have to a large extent confined my attention to research in pure science, agriculture and industry. I am, however, not unmindful of the pressing needs of India to alleviate the sufferings of the people from attacks of malaria and other tropical diseases. I know that India herself is giving much thought to these vital problems in which science can give her valuable help.

Transmutation of Matter.

I have so far spoken of the importance of science as a factor in national development, but before concluding my address, I would like to refer to some investigations in pure science in which I have been personally much interested. I refer to the successful attack on that age-old problem of the transmutation of matter which in recent years has attracted so much attention from physicists throughout the world.

I hope it may prove of interest to give a brief account of the successive stages of the growth of our knowledge of this subject, for it illustrates in a striking manner the power of the scientific method of attack on what at first appeared to be an insoluble problem. Incidentally these researches have yielded us precious information on the structure of all atoms and indeed it seems likely to have provided us with a key, so to speak, to unlock the secrets of the constitution of our material world.

Towards the close of the nineteenth century, when it seemed certain that the atoms of the elements were unchangeable by the forces then at our command, the discovery was made which has revolutionized our conception of the nature and relations of the elements. I refer to the discovery in 1896 of the radioactivity of the two heaviest elements uranium and thorium. It was soon made clear that this radioactivity is a sign that the atoms of these elements are undergoing spontaneous transmutation. At any moment, a small fraction of the atoms concerned becomes unstable and breaks up with explosive violence, hurling out either a charged atom of helium, known as an α-particle, or an electron called in this connection a β-particle. As a result of these explosions, a new radioactive element is formed and the process of transmutation once started continues through a number of stages. Each of the radioactive elements, formed in this way, breaks up according to a simple universal law but at very different rates. In a surprisingly short time, these successive transformations were disentangled and more than 30 new types of elements brought to light while the simple chemical relations between them were soon made clear.

We had thus been given a vision of a new and startling sub-atomic world where atoms break up spontaneously with an enormous release of energy, quite uninfluenced by the most powerful agencies at our disposal. Apart from uranium and thorium and the elements derived from them, only a few other elements showed even a feeble trace of radioactivity. The great majority of our ordinary elements appeared to be permanently stable under ordinary conditions on our earth. Science was then faced with the problem whether artificial methods could be found to transmute the atoms of the ordinary elements. Before this problem could be attacked with any hope of success, it was necessary to know more of the actual constitution of atoms. This information was provided by the rise of the nuclear theory of the atomic structure which I first suggested in 1911. The essential controlling feature of all atoms was found to reside in a very minute central nucleus which carried a positive charge and contained most of the mass of the atom. A relation of unexpected simplicity was found to connect the atoms of all the elements. The ordinary properties of an atom are defined by a whole number which represents the number of units of resultant positive charge carried by the nucleus. This varies from 1 for hydrogen to 92 for the heaviest element uranium and with few exceptions all the intervening numbers correspond to known elements.

On this view of atomic structure, it was evident that, to bring about the transmutation of an atom, it was necessary in some way to alter the charge or mass of the nucleus or both together. Since the nucleus of an atom must be held together by very powerful forces, this could only be effected by bringing a concentrated source of energy in some way to bear on the individual nucleus. The most energetic projectile available at that time was the α-particle spontaneously ejected from radioactive substances. If a large number of α-particles were fired at random at a sheet of matter, it was to be expected that one of them must occasionally approach very closely to the nucleus of any light atom in its path. In such a close encounter, the nucleus must be violently disturbed, and possibly under favourable conditions the α-particle might actually enter the nuclear structure, resulting in a transformation of the nucleus.

This mode of attack upon the nucleus at once proved successful. I found in 1919 that nitrogen could be transformed by bombardment with fast α-particles. The process of transmutation is now clear. Occasionally an α-particle actually enters the nitrogen nucleus and forms with it a new unstable nucleus which instantly breaks up with the emission of a fast proton (hydrogen nucleus) and the formation of a stable isotope of oxygen of mass 17. About a dozen of the light elements were found to be transformed in a similar way. The protons liberated in the nuclear explosions were at first counted by observing the flashes of light (scintillations) produced in phosphorescent zinc sulphide. This method was slow and very trying to the eyes of the observers. Progress however became more rapid and definite when electrical methods of counting individual fast particles were developed. These electrical counters, mainly depending on the use of electron-tubes for magnifying small currents, have now reached such a stage of perfection that we are able to count automatically individual fast particles like α-particles and protons, even though they enter the detecting chamber at a rate as fast as ten thousand per minute. By other special devices, we are in like manner able to count individual β-particles. In this connection, I must also mention that wonderful instrument the Wilson Expansion Chamber which makes visible to us the actual tracks of flying fragments of atoms resulting from an atomic explosion. These remarkable devices have played an indispensable part in the rapid growth of knowledge during the last few years. It is to be emphasized that progress in scientific discovery is greatly influenced by the development of new technical methods and of new devices for measurement. With the growing complexity of science, the development of special techniques is of ever increasing importance for the advance of knowledge.

Up to the year 1932, experiments on transmutation were confined to the use of α-particles for bombarding purposes. It became clear that the process of transformation was in most cases complex, since groups of protons with different but characteristic energies were observed when a single element was bombarded. This led to the conception that discrete energy levels existed within a nucleus and that under some conditions part of the excess energy was sometimes released in the form of a quantum of high frequency radiation.

The stage was now set for a great advance, and four new discoveries of outstanding importance were made in rapid succession in the period 1932-3. I refer to the discovery of the positive electron by Anderson in 1932, of the neutron by

Chadwick in 1932, of artificial radioactivity by M. and Mme. Curie-Joliot in 1933 and of the transmutation of the elements by purely artificial methods first shown by Cockcroft and Walton in 1932.

The discovery of the neutron—that uncharged particle of mass nearly 1—was the result of a close study of the effects produced in the light element beryllium when bombarded by α-particles. It is noteworthy that the proton and the neutron, which are now believed to be the essential units with which all atomic nuclei are built up, owe their recognition to a study of the transmutation of matter by α-particles.

Before the discovery of the neutron, it had been perforce assumed that nuclei must in some way be built up of massive protons and light negative electrons. Theories of nuclear structure became much more amenable to calculation when the nucleus is considered to be an aggregate of particles like the proton and neutron which have nearly the same mass. There was no longer any need to assume that either the positive or the negative electron has an independent existence in the nuclear structure. We are still uncertain of the exact relation, if any, between the neutron and the proton. The neutron appears to be slightly more massive than the proton but it is generally believed, although no definite proof is available, that the proton and neutron within a nucleus are mutually convertible under certain conditions. For example, the change of a proton into a neutron within the nucleus should lead to the appearance of a free positive electron, while conversely the change of a neutron into a proton gives rise to a free negative electron. In this way it appears possible to account for the observed fact that either positive or negative electrons are emitted by a large group of radioactive elements, to which I will now refer.

In the early experiments on transmutation by α-particles, it was supposed that a stable nucleus was always formed after the emission of a fast proton. The investigations of M. and Mme. Curie-Joliot showed that in some cases elements were formed which, while apparently stable, ultimately broke up slowly, exactly like the natural radioactive bodies. Most of these radioactive bodies, formed by artificial methods, break up with the expulsion of fast negative electrons, but in a few cases positive electrons are emitted. Since the presence of these radioactive bodies can be easily detected, and their chemical properties readily determined, this new method of attack on the problem of transmutation has proved of great value. Nearly a hundred of these radioactive bodies are now known, produced in a great variety of ways. Some arise from the bombardment by fast α-particles, others by bombardment with protons or deuterons. As Fermi and his colleagues have shown, neutrons and particularly slow neutrons are extraordinarily effective in the formation of such radioactive bodies. On account of its absence of charge, the neutron enters freely into the nuclear structure of even the heaviest element, and in many cases causes its transmutation. For example, a number of these radioactive bodies are produced when the two heaviest elements uranium and thorium are bombarded by slow neutrons. In the case of uranium, as Hahn and Meitner have shown, the radioactive bodies so formed break up in a succession of stages like the natural radioactive bodies, and give rise to a number of transuranic elements of higher atomic number than uranium (92). These radioactive elements have the chemical properties to be expected from the higher homologues of rhenium, osmium and iridium of atomic numbers 93, 94 and 95 respectively.

These artificial radioactive bodies in general represent short-lived varieties of the isotopes of known elements. No doubt such transient radioactive elements are still produced by transmutation in the furnace of our sun where the thermal motions of the atoms must be very great. These radioactive elements would rapidly disappear as soon as the earth cooled down after separation from the sun. On this view, uranium and thorium are to be regarded as practically the sole survivors in our earth of a large group of radioactive elements owing to the fact that their time of transformation is long compared with the age of our planet.

It is of interest to note what an important part the α-particle, which is itself a product of transformation of the natural radioactive bodies, has played in the growth of our knowledge of artificial transmutation. It is to be remembered too that our main source of neutrons for experimental purposes is provided by the bombardment of beryllium with α-particles. The amount of radium available in our laboratories is, however, very limited, and it was early recognized that if our knowledge of transmutation was to be extended, it was necessary to have a copious supply of fast particles of all kinds for bombarding purposes. It is well known that enormous numbers of protons and deuterons, for example, can be easily produced by the passage of the electric discharge through hydrogen and deuterium (heavy hydrogen). To be effective for transmutation purposes, however, these charged particles must be given a high speed by accelerating them in a strong electric field. This has involved the use of apparatus on an engineering scale to provide voltages as high as one million volts or more and the use of fast pumps to maintain a good vacuum.

A large amount of difficult technical work has been necessary to produce such high direct voltages, and to find the best methods of applying them to the accelerating system. In Cambridge, these high voltages are produced by multiplying the voltage of a transformer by a system of condensers and rectifiers; in the U.S.A. by the use of a novel type of electrostatic generator, first developed by van der Graaf. Prof. E. O. Lawrence of the

University of California has devised an ingenious instrument called a 'cyclotron', in which the charged particles are automatically accelerated in multiple stages. This involves the use of huge electromagnets and very powerful electric oscillators. By this method, he has succeeded in producing streams of fast particles which have energies even higher than α-particles ejected from radioactive substances. Undoubtedly this type of apparatus will prove of great importance in giving us a supply of much faster particles than we can hope to produce by the more direct methods.

It was at first thought that very high potentials of the order of several million volts would be required to obtain particles to study the transmutation of elements. Here, however, the development of the theory of wave-mechanics came to the aid of the experimenter, for Gamow showed that there was a small chance that comparatively slow bombarding particles might enter a nucleus. This theoretical conclusion has been completely verified by experiment. In the case of a light element like lithium, transformation effects can be readily observed with protons of energy as low as 20,000 volts. Of course, the possibility of transformation increases rapidly with rise of voltage.

The study of the transmutation of elements by using accelerated protons and deuterons as bombarding particles has given us a wealth of new information. The capture of the proton or deuteron by a nucleus leads in many cases to types of transmutation of unusual interest. For example, the bombardment of the isotope of lithium of mass 7 by protons leads to the formation of a beryllium nucleus of mass 8 with a great excess of energy. This immediately breaks up with two α-particles shot out in nearly opposite directions. When boron of mass 11 is bombarded by protons, a carbon nucleus of mass 12 is formed which breaks up in most cases into three α-particles. The deuteron is in some respects even more effective than the proton as a transmuting agent. When deuterons are used to bombard a compound of deuterium, previously unknown isotopes of hydrogen and of helium of mass 3 are formed, while fast protons and neutrons are liberated. The bombardment of beryllium by very fast deuterons gives rise to a plentiful supply of neutrons. Lawrence has shown that the bombardment of bismuth by very fast deuterons leads to the production of a radioactive bismuth isotope which is identical with the well-known natural radioactive product radium E. Many artificial radioactive elements can be produced often in great intensity. For example, the bombardment of common salt by fast deuterons gives rise to a radioactive isotope of sodium. This breaks up with a half period of 15 hours, emitting not only fast β-particles but γ-rays at least as penetrating as those from radium.

It may well be that in course of time such artificial radioactive elements may prove a useful substitute for radium in therapeutic work. By these methods also, such intense sources of neutrons can be produced that special precautions have to be taken for the safety of the operators of the apparatus.

Sufficient I think has been said to illustrate the variety and interest of the transmutations produced by these bombardment methods. It should, however, be pointed out that transmutation in some cases can be effected by transferring energy to a nucleus by means of gamma rays of high quantum energy instead of by a material particle. For example, the deuteron can be broken up into its components, the proton and neutron, by the action of the gamma rays from radium or thorium. As a result of the bombardment of lithium by protons, gamma rays of extraordinarily high energy up to 17 million volts are strongly emitted. Bothe has recently shown that these high energy rays are able to transmute a number of atoms, neutrons usually being emitted in the process.

Some simple laws appear to hold in all individual transformations so far examined. Nuclear charge is always conserved, and where heavy particles are emitted, so also is energy when account is taken of the equivalence of mass and energy. Certain difficulties arise with regard to the conservation of energy in cases where light positive and negative electrons are emitted during transmutation, and there is still much discussion on this important question.

The study of the transmutation of matter has been extraordinarily fruitful in results of fundamental importance. In addition to the α-particle, it has disclosed to us the existence of those two building units of nuclei, the proton and neutron. It has greatly widened our conception of the varieties of atomic nuclei which can exist in nature. Not only has it led to the discovery of about one hundred new radioactive elements, but also of several stable isotopes of known elements like ^{3}H, ^{3}He, ^{8}Be which had previously been unsuspected. It has greatly extended our knowledge of the ways in which nuclei can be built up and broken down, and has brought to our attention the extraordinary violence of some of the nuclear explosions which occur. The great majority of our elements have been transmuted by the bombardment method, and in the case of the light elements which have been most carefully studied, a great variety of modes of transmutation have been established.

Rapid progress has been made but much still remains to be done before we can hope to understand the detailed structure and stability of different forms of atomic nuclei and the origin of the elements. I cannot but reflect on the amazing contrast between my first experiment on the transmutation of nitrogen in the University of Manchester in 1919 and the large-scale experiments on transmutation which are now in progress in many parts of the world. In the one case, imagine an observer in a dark room with very simple apparatus painfully counting with a microscope a few faint scintillations originating from the bombardment of nitrogen by a source of α-particles. Contrast this with the large scale apparatus now in use for experiments on transmutation in Cambridge. A great hall contains massive and elaborate machinery, rising tier on tier, to give a steady potential of about two million volts. Nearby is the tall accelerating column with a power station on top, protected by great corona shields—reminding one of a photograph in the film of Wells's 'Things to Come'. The intense stream of accelerated particles falls on the target in the room below with thick walls to protect the workers from stray radiation. Here is a band of investigators using complicated electrical devices for counting automatically the multitude of fast particles arising from the transformation of the target element or photographing with an expansion chamber, automatically controlled, the actual tracks of particles from exploding atoms.

To examine the effect of still faster particles, a cyclotron is installed in another large room. The large electromagnet and accessories are surrounded with great water tanks containing boron in solution to protect the workers from the effect of neutrons released in the apparatus. A power station nearby is needed to provide current to excite the electromagnet and the powerful electric oscillators.

Such a comparison illustrates the remarkable changes in the scale of research that have taken place in certain branches of pure science within the last twenty years. Such a development is inevitable, for, as science progresses, important problems arise which can only be solved by the use of large powers and complicated apparatus, requiring the attention of a team of research workers. If rapid progress is to be made, such team work is likely to be a feature of the more elaborate researches in the future. Fortunately there is still plenty of scope for the individual research worker in many experiments of a simpler kind.

The science of Physics now covers such a vast field that it is impossible for any laboratory to provide up-to-date facilities for research in more than a few of its branches. There is a growing tendency in our research laboratories to-day to specialize in those particular branches of Physics in which they are most interested or specially equipped. Such a division of the field of research amongst a number of universities has certain advantages, provided that this subdivision is not carried too far. In general, the universities should be left free as far as possible to develop their own lines of research and encouraged to train young investigators, for it cannot be doubted that vigorous schools of research in pure science are vital to any nation if it wishes to develop effectively the application of science, whether to agriculture, industry or medicine. Since investigations in modern science are sometimes costly and often require the use of expensive apparatus and large scale collaboration, it is obviously essential that adequate funds should be available to the universities to cover the cost of such researches.

In this brief survey, I have tried to outline the contributions to scientific knowledge made in India, and the needs of the immediate future if science is to play its part in the national welfare. While the study of modern science in India is comparatively recent, and naturally much influenced by Western ideas, it is well to recall that India in ancient days was the home of a flourishing indigenous science which in some respects was at the time in advance of the rest of the world.

The study of ancient writings has disclosed in recent years the extent and variety of these scientific contributions. Much progress was made in the study of arithmetic and geometry, while the researches of Sir Prafulla Ray have brought to light the important advances made in metallurgy and chemistry. May we not hope that this natural aptitude for experimental and abstract science, shown so long ago, is still characteristic of the Indian peoples, and that in the days to come India will again become a stronghold of science, not only as a form of intellectual activity but as a means of furthering the progress of her peoples.

SECTION OF MATHEMATICS AND PHYSICS

President:—C. W. B. NORMAND, C.I.E., M.A., D.Sc., F.N.I.

Presidential Address

THE SOURCES OF ENERGY OF STORMS

During the year we have lost by death[1] one of our past Presidents, J. H. Field, and one of our most noteworthy. He was first of his year (1903) in Physics at Cambridge, had considerable mechanical ability and was a keen promoter of the cause of meteorology. He had vision and in addition had the character and personality to persuade a Government to many of his views. He originated the network of upper air and pilot balloon stations in India. We, who use the extensive data that have been collected during the past 25 years, may not often refer to Field by name, just because he was so thoroughly self-effacing amongst fellow scientists and wrote few papers himself, but we should not forget the debt we owe him.

The collection of data of the upper air has introduced a gradual revolution in the study and practice of meteorology in India, as it has done over the rest of the world. In my own experience the forecaster's methods have altered much. Whereas 25 years ago scanty data regarding cloud furnished almost the only indications of the ongoings within the ocean of air, to-day the forecaster has small auxiliary charts of streamlines for the levels of ½, 1, 2 km. and for a few higher levels up to 6 km, if low clouds do not intervene. The meteorologist as well as the aviator has reason to be grateful for these high-level charts which, along with the physical conceptions and methods of analysis introduced by the Norwegian school of meteorologists, are helping to lift the practice of forecasting out of its deep empirical ruts on to a plane where physical principles are directly applicable. The empirical stage was inevitable and has not yet ended; and the experienced empiricist could forecast very successfully on the whole; but I believe the forecaster of the newer type will, when he has had the same experience, be better still and certainly will have found weather forecasting to be a much more interesting exercise than it used to be. Contrast the man who is content simply to forecast 'rain' with one who tries, at the same time, to picture the process of the rain-formation. The latter sees the physical problem. Will the rain, he asks himself, be caused by the gradual upward glide of one air mass over another at a gentle angle, producing steady continuous rain; will it be the result of a convective break-through, of the shower or thunderstorm type; or will it be a gentle drizzle due to convergence and fall of pressure only? These are questions intimately associated with the sources of energy and the kinds of instability that occur in the atmosphere, questions to which I wish to devote special attention to-day.

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[1] In the spoken address reference was also made to the deaths of Lord Rutherford and Sir J. C. Bose.

The general theme of my remarks concerns the thermodynamical approach to the study of storms of all kinds, cyclones, thunderstorms, duststorms on the lines laid down by Margules during 1903 to 1906. At the basis of Margules' work and therefore of all that I have to say, there is the simple enough proposition, namely;—if the whole air mass around and including a storm can be circumscribed and considered as a closed system, it should be possible from a study of the initial and final conditions alone to decide the main source of the kinetic energy that has been created and displayed during the storm's existence. I am going to assume for the present that the energy does not come from the stratosphere,[1] which is beyond the scope of our daily weather charts and even beyond the ordinary reach of our instruments. Also we shall ignore for the present without discussion the possibility that there may occur a redistribution of kinetic energy alone without alteration of any other kind of energy, one central part of the system gaining in kinetic energy at the expense of the whole outer field. With these fundamental assumptions, we can, following Margules, simplify the discussion of sources of energy. The increase of kinetic energy in the storm's field must be explained by a transformation from some other forms of energy stored within the closed system. The other forms of energy are the gravitational and thermal (or internal). Margules previously in 1901 had considered the contribution from the potential energy of the pressure gradient only, which is really a fraction of the energy included under the thermal or internal energy. Can, he enquired, the kinetic energy of storms be a result of the pressure gradients alone? If all pressure differences over any area are suddenly abolished, will the energy thus set free be equivalent to the kinetic energy generally associated with a storm? His answer, if not his analysis, is clear enough, namely, this source of energy alone is quite insufficient. This answer nullifies a theory which had been put forward by another great Austrian meteorologist J. von Hann to explain the energy of tropical storms. Curiously enough, Hann brought his theory to notice again in *Nature* of 3rd March, 1921, but it does not, to my mind, bear critical examination. Now before either the gravitational or the internal energies can decrease within a closed system the stored-up energy must be present in a state of instability actual or potential. The possible diversities of instability, though numerous, are believed to be composites of three main kinds, which I shall call for brevity, the vertical, horizontal and latent types. The vertical and horizontal types refer to the behaviour of dry air, or at least air which is dry enough to remain unsaturated during the changes considered.[1] The latent instability is that which arises from the latent heat of water vapour.

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[1] The sources of energy in the stratosphere have not yet been shown to be comparable in power with those of the troposphere. If the stratosphere has an important rôle in initiating tropospheric processes, it may act more as a trigger than as a source of energy. In any case, the more easily observable sources of energy within the troposphere itself are still awaiting full discussion based on adequate facts.

INSTABILITY FROM VERTICAL DECREASE OF ENTROPY

The limit for stability is reached when the vertical gradient of temperature (or the lapse-rate, as it is ordinarily referred to in meteorology) becomes that of convective equilibrium, in which the air temperature decreases upwards about 9·8°C. every kilometre. The air has then the same entropy everywhere and no work is done in transferring a unit of it to any other level. Wherever the air unit is moved, it automatically changes pressure and temperature to agree with its surroundings. When this limit is passed, instability sets in. Now liquids in a jar or strata in the ocean set themselves according to density, but the layers in the atmosphere always tend to take up positions according to their entropies—those of greatest entropy uppermost. Usually, indeed, the entropy of dry air does increase upwards. The average lapse-rate is not 9·8°C. but only about 6°C. per kilometre. The best picture of the normal atmosphere is that stressed by Sir Napier Shaw of stratified layers, each resilient and to a certain degree obstinate and resistant towards any attempt towards upwards or downward motion of other masses of air through it. We see evidence of this normal feature in the tendency of many clouds to form in layers. The degree of stratification varies and sometimes is pierced or broken down altogether, usually, as we shall see, by the latent heat of water vapour, but sometimes over shallow depths by the lapse-rate exceeding that of convective equilibrium—by this vertical type of instability, as we have called it. The sun's heat on the ground is a potent agent in creating vertical instability. It makes the surface layer unstable over tropical land every sunny day. There's a tendency for this type of instability to develop, too, whenever the upper layers come from a colder source than the lower layers. Yet, despite its significance as a weakener of resistance or, as we shall see later, as a kind of trigger, it is not of prime importance in the study of a storm's energy, because; behind it, there is no means of storing up energy. The only checks to the immediate development of a vertical circulation, when the lapse-rate passes beyond the dry adiabatic, are the viscous forces, which in the main body of the atmosphere may impede the vertical circulation a little but never help to build up any important reservoir of energy.

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[1] This condition is introduced here for simplicity of discussion. In actual examples air may become saturated, but if originally it has no convective instability there is no additional instability produced as a result of the condensation within the closed system.

INSTABILITY FROM HORIZONTAL CHANGE OF TEMPERATURE.

This second type of instability is exemplified by a warm and a cold current of air moving parallel to each other. We are all accustomed nowadays to the notion of the meeting of air masses from different parts of the earth, of polar air encountering tropical air, or monsoon air coming into proximity with continental air. Ordinarily, one might expect two such currents when brought alongside one another to react immediately. On a rotating earth however (as Helmholtz and Margules first proved for us) an equilibrium position can be set up. Any mass that moves on the earth experiences, on account of the earth's rotation, a force tending to push it to the right. So, if a warm air current is moving relatively past a cold current of air on its right, it exerts a pressure by virtue of its motion, which tends to counteract the extra pressure or weight of the cold air. In the position of equilibrium the surface of discontinuity has a slope that depends upon the relative motion of the two currents, the latitude and the difference in temperature. The important aspect of this from the point of view of the present discussion is that here is a means of storing up energy. So long as the surface of discontinuity is in equilibrium, a large difference of temperature may be maintained in adjacent air masses. When the position of equilibrium is broken down by any agency, perhaps by a pronounced pressure wave, there is obviously a considerable store of potential energy readily available for transformation into the kinetic form of wind and gale, the cold air breaking through with all the display of a 'line squall' or 'cold front'. The Norwegian school of meteorologists, under B. Bjerknes, regard the cyclone of temperate latitudes as a wave on a surface of discontinuity, the wave partly modifying by its own energy the kinetic energy already present in the currents and partly utilizing the potential energy of position to overcome the viscous forces and to nourish any development that may occur.

INSTABILITY DUE TO WATER VAPOUR.

(*a*) *Convective Instability and Wet-bulb Temperature.*—The third main type of instability arises from the latent heat of water vapour and is dependent upon the power of vapour in the atmosphere to act as a reservoir of energy. Just as there is a limit to the lapse-rate of temperature for dry air, so there is a limit to the lapse-rate of wet bulb temperature, which on being exceeded is a potential source of energy. This type of instability has been named 'Convective Instability' by Rossby, because a layer with this property will, if lifted adiabatically and bodily, become saturated and then be in an unstable state, analogous to the superadiabatic condition for dry air. Kinetic energy is set free in the stabilizing process, which ensues when each unit of saturated air seeks to reach its proper entropy level. I defined convective instability with reference to the lapse-rate of wet bulb temperature, because in all adiabatic movements in the atmosphere the wet bulb temperatures have an importance of their own, and especially so, in those processes in which evaporation or condensation occurs. The (ventilated) wet bulb temperature is an interesting physical entity, worthy of a little more attention than it ordinarily receives in text-books of physics, where it is treated as a mere stepping stone towards the determination of relative humidity. The wet bulb temperature has other practical aspects. When the householder in northern India keeps his rooms cool in the hot weather by placing wet grass screens on the doors that face windward, he reduces the dry bulb temperature greatly but, though he may not always realize it, he leaves the wet bulb unaltered. The value of the wet bulb temperature lies in it being a measure (though non-linear) of the heat content of a mixture of air and water-vapour, taking latent heat into account. For example, the engineer, when faced with problems of air-conditioning knows that no purely evaporative method can cool air at the ordinary temperature to any point lower than the wet-bulb temperature. If he has to aim at a lower air temperature than the wet bulb, he must adopt a different method, instal a refrigeration plant or have a plentiful supply of really cold water to aid him. The processes taking place at a wet bulb are adiabatic, though irreversible and therefore not quite isentropic.

The criterion for 'convective instability', which we shall consider graphically later on, is of a very general nature. It takes account of the wet bulb temperature, but none of the associated relative humidity or of the general stability of the air column. The whole air mass may in fact be so stable that the potential energy of the layer of convective instability may never be realized at all or, if it is, may be very small in comparison with the amount of work needed to raise the layer to the point of realization. Throughout our dry weather season in Poona, a time of settled weather, the association of 'convective' instability with general stability is a common feature, showing that convective instability has no necessary association with disturbed weather, and that, to arrive at a more practical criterion, the definition of the instability due to water vapour must be narrowed down.

One interesting feature however of convective instability is its relationship with the problem of vertical convection or eddy-conduction of heat or entropy. When convective instability exists, we know that the entropy of the mixture, air plus water-vapour, decreases upward and that turbulence must then tend to carry entropy upwards. If the presence of water vapour is ignored, one may be tempted to deduce that turbulence works almost completely towards carrying entropy downwards, because the lapse-rate is less than the adiabatic. Taking account however of the latent heat and noting that convective instability is practically always present in the lower layers of equatorial air throughout the year and in temperate latitudes in the summer months, and that turbulence is greatest in the day-time when the lapse-rate of temperature is greatest, we see that the carriage of entropy from the ground upwards by turbulence may be a more important process than it was at one time believed to be.

(*b*) *Latent Instability.*—Refsdal in Norway was the first to explain clearly certain essential conditions for the storage of energy by water vapour and introduced the phrase 'feuchtlabil' to describe the associated type of instability. Almost simultaneously a slightly different approach was made in India to this problem. A kind of metastable condition was recognized and defined as 'latent instability'.

The importance of the latter will become more obvious when we go on to consider a thermodynamically closed system. The essential point is this:—let the metastable or 'latent' state be disturbed by a trigger, then the ensuing release of energy is large compared with that supplied by the trigger. It is an interesting type of instability because it can develop behind a veneer of stability. It is of the same type as a vertically expanding pencil standing on end, or analogous to a hydrogen balloon caught in the corridor of a large hall where it can be fed with more and more hydrogen, but cannot escape up to the dome until given a small push. A balloon in this state is stable for small but unstable for large displacements. So also a quantum of air in the atmosphere, that is in the state of 'latent' instability due to water vapour, will respond to large but not to small displacements. The instability may develop in various ways, for example, in an otherwise homogeneous air mass, if the lower layers of the air pass over a sea, which is considerably warmer than the wet bulb temperature of the air; or if the air passes over warm moist soil. Alternatively, convective or latent instability may arise in a column of air, of which the upper and lower layers have different origins, the lower layer coming from a warm moist source. In Bengal one may recognize this condition in the winds of the hot weather and the nor'wester months, when the lower winds are from the Bay of Bengal and the upper winds from northern India. In general, an oceanic current in the lower layers appears to be essential for the development of latent instability in India.

The atmosphere has various means of releasing the energy of latent instability. Over the land the most common trigger is the heating up of the surface layers in the day-time, creating instability of the vertical type. We see the result in the duststorms and thunderstorms of the afternoon and evening hours. Another trigger is convergence of air, which acts on the air layers like the lateral squeezing of a rubber sponge causing vertical extension and therefore altering the lapse-rate in a fashion favourable for release of energy. A third type of trigger is horizontal instability, i.e. the presence of another air mass in the neighbourhood, which may be shallow and yet by undercutting the warmer moist air may raise it just sufficiently to overcome the initial resistance.

MARGULES; AND QUANTITATIVE ESTIMATES OF AVAILABLE ENERGY.

These are the main types of instability and we wish to have a means of estimating quantitatively their relative importance in originating storms. Margules' thirty-year-old discussion of this point, particularly on the vertical and horizontal types of instability, is full and illuminating.

Regarding the energy available from latent heat of condensation, Margules' method of approach was interesting but not sufficiently complete. At one time he concluded from his quantitative studies that the latent heat of condensation had little influence on the development of a storm and contributed little or nothing to the sum total of its kinetic energy. In his final[1] contribution to Meteorology (1906) he conceded some importance to the heat of condensation in tropical storms, but not in those of temperate latitudes, and even in the tropical storms he thought that the potential energy dependent upon the horizontal distribution of temperature would prove to be of chief importance, only a part of the latent heat of condensation being transformed into kinetic energy and therefore playing a subsidiary rôle.

Margules' analysis and methods remain the standard to this day. His papers perhaps have not been studied by meteorologists as closely as they deserve to be; they are not easy to read and the full implications of his analysis are not easy to grasp. Although he offered approximate simple solutions for some cases, his main applications to particular cases involved arduous computations; pressures at various heights as well as all the subsequent computations were calculated with a high degree of accuracy, because the final result depends upon the small difference between two large quantities, e.g. between 233·5132 and 233·4140, as in one of his now classical, oft-quoted examples. The present is an appropriate occasion to recall some of his examples, because we have seen recently how graphical methods may be borrowed to clarify and extend Margules' work, have understood more clearly the conditions under which latent heat may be of great importance in storm development and my colleagues are using these ideas in certain investigations in Indian meteorology, in which the general aim has been to begin once more from fundamental principles with the aid of upper air observations, and to see if by a comparative study of the initial and final 3-dimensional fields of temperature and humidity it is possible to conclude which type of instability, vertical, horizontal or latent, is mainly operative in various typical situations. If a decision can be reached, it will guide further investigations and ease the study of the dynamical aspects.

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[1] He lived until 1920, but unfortunately wrote no more on meteorological subjects.

The quantitative discussion that follows of some very simple types may lead one to think that they are too simplified to cover the complex processes of the atmosphere and understate the possibilities to such an extent that the final conclusion, whatever it may be, will have little application in nature. The meteorologist knows the danger of this full well, but the human mind cannot advance a subject without making abstractions; and these particular abstractions are useful and believed to be adequate. After all, unless we have some clear fundamental ideas to build upon, it is difficult to discern whether different workers are discussing matters at cross purposes, or in their discussion of complex situations how far they are on common ground.

In order to express Margules' main results graphically, it is necessary to include the use of a type of diagram, adapted for meteorological computations, in which area is proportional to energy. It may be a p–v diagram, or T–log p, or log T–T log p, or a temperature-entropy diagram.

The temperature-entropy diagram or tephigram.—I choose the temperature-entropy diagram, for the meteorological form

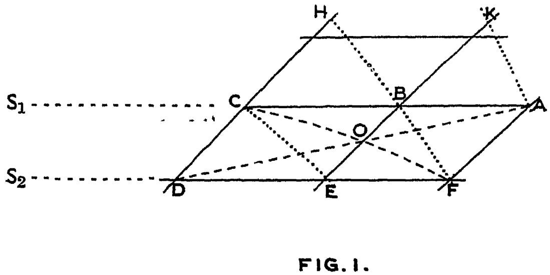

FIG. 1.

of which we are indebted, along with so many other ideas, to Sir Napier Shaw. Meteorologists are familiar enough with this form of the temperature-entropy diagram, briefly called the tephigram; as others may not be, I must introduce a brief description of it here. The ordinate is entropy of dry air, increasing upwards, and the abscissa temperature increasing to the right. Isothermals are vertical lines. Isentropics like *AC* and *FD* of fig. 1 are horizontal. Now entropy is a function of pressure and temperature. So, isobars are also entered on the diagram. They are almost straight diagonal lines (e.g. *AF*, *KE*, *HD* of fig. 1) representing values of pressure that decrease towards the top left hand corner. The pressure and temperature of a unit of air being known, it can be represented by a point at the intersection of the appropriate isobar and isothermal. The entropy can then be read off, if required.

Before going on to the discussion of stability, let me show a less sketchy form of the tephigram in a guise, in which it is used for much aerological work, particularly for entering aeroplane ascents. To illustrate the extent of the diagram and how and where observations appear on it I have entered strips, representing the normal variation of the mean daily temperature of Calcutta, Darjiling, top of Mt. Everest (conjectural, of course), London, Sonnblick at 3000 m. in the Alps and some temperatures taken near the bottom level of a mine in the Kolar Gold Fields (Mysore), when the ventilation was good. I enter the observations of the bottom of a deep mine, as a reminder to ventilation engineers that charts like these offer an alternative method of approach to ventilation problems and allow the actual dry and wet bulb temperatures down a shaft to be compared with those theoretically obtainable when air is driven down the shaft adiabatically.

This diagram also contains curved lines, almost at right angles to the isobars. These indicate how the effect of the latent heat of condensation is allowed for on a temperature-entropy diagram. It is an adaptation of the graphical method introduced by H. Hertz 53 years ago. Ascending saturated air forms cloud and so gets a contribution from latent heat to lessen its lapse-rate. Accordingly, the fall of temperature from isobar to isobar is less on the saturated adiabat than on the dry. The isentropies of a saturated mixture therefore appear as these curved lines (*cf. AK*, *FH*, *EC* of fig. 1). We may label them as the family of $\acute{S}$-curves and remember that they are related to the entropy of moist air, i.e. the entropy of a mixture of air and vapour, of which the latent heat is taken into account. Now, when air is saturated, the wet and dry bulb temperatures are identical. Hence an $\acute{S}$-curve traces the course of the wet, as well as of the dry, bulb temperatures of saturated air in adiabatic movements. To a certain degree of approximation, sufficient for practical purposes, they trace also the course of the wet bulb temperatures in all adiabatic movements, even when the air is not saturated. Another function can be defined that has an exact relationship with the $\acute{S}$-curves, but we make use, in what follows, of the approximate correspondence with wet bulb temperatures, because the latter are familiar to us all, and ordinarily available in meteorological practice. For the discussion of questions of stability, when condensation or evaporation is part of the processes at work, the wet bulb temperatures as well as the dry are entered against the appropriate pressures on the temperature-entropy diagram. Here, for instance, is how soundings representative of average conditions in January and July at Agra appear on tephigram paper, both dry and wet bulb curves.

One more point concerning these $\acute{S}$-curves. Each can be given a number corresponding to the point where they cut the standard pressure. This value represents the wet bulb temperature of the unit of air, if reduced to standard pressure and so is called the 'wet bulb potential temperature',—a most useful function in meteorology, because it is an invariant in all adiabatic processes, even if evaporation or condensation occurs.

Energy from vertical instability (discontinuous change).—Mathematically the simplest case of vertical instability to consider is one in which an air mass of entropy S_2 is superposed above another of entropy S_1 where S_1 is greater than S_2, the whole forming a closed system with a frictionless piston of constant weight on top. The maximum release of energy is achieved when the process is adiabatic and the two layers do not mix but readjust themselves to the equilibrium position as if each remained in its own perfectly flexible, frictionless, weightless envelope, as if indeed the movement resembles that of the overturn of a water-oil system, in which water is originally on top of the oil and finishes below. The change is illustrated in fig. 2,[1] position (*a*) changing to position (*c*). The energy, that is released during the change, arises from the fall of the centre of gravity of the system and from a certain decrease in the internal energy. What does that energy amount to?

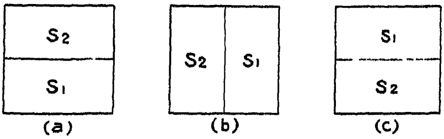

FIG. 2.

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[1] These graphical methods can be extended to examples in which the air columns in fig. 2, *a* and *b*, are not isentropic, but I have not the time to develop these points here.

On the tephigram a solution can be given that is both simple and valid to a high degree of approximation. The system is represented by (*cf.* fig. 1)—

(*a*) initial condition : *AB*, representing column S_1,
and *ED*, representing column S_2.

The air temperature of the whole column is represented by *ABED*. When this overturns adiabatically, the air in S_1 retains its entropy, so that *AB* moves up to *BC*. Similarly the layer *ED* moves down along the isentropic to *FE*. Hence—

(*b*) final condition : *FE*, representing column S_2,
and *BC*, representing column S_1.

Now the tephigram is ordinarily intended to indicate the work done by or on a unit mass of the working substance. The lines *AB* and *ED* in this instance give us the environment within which the particles give up or receive their energy. It is easy to see that the first upward moving unit and the first downward moving unit each gain energy corresponding to one half the area *ACDF*. Other particles gain less energy. To integrate the energy for the whole mass, we may imagine an ordinate perpendicular to the paper (in fig. 1) representing mass. The total energy is given approximately by the volume of a wedge on the base *ACDF*, with edge uppermost and at a height of $M/2$, if M is the total mass. Hence the total energy is $(M/4) \times$ (area *ACDF*), and the average energy per unit mass, obtained by dividing the total by M, is $\frac{1}{4}$th the area *ACDF*. When the height of each column is 2000 m. and the difference between them at the discontinuity is 3°C. the average kinetic energy computed from the tephigram is 14·7 m.p.s. (or 33 miles an hour) compared with 14·85 m.p.s. computed more laboriously by Margules.

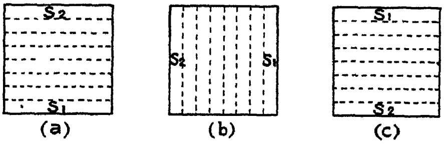
It is quite obvious that all units will not gather the same amount of kinetic energy,—some will have more, others less—and that a proportion will be dissipated during the movement by eddy viscosity, which in turn introduces irreversible and inefficient changes, decreasing the available energy. The 14·7 m.p.s. represents a *maximum value* for the *average* velocity that can be produced by the change. So also in all the following examples, only the *maximum* possible value of the average velocity will be mentioned ; and all the processes of mixing and turbulence that lead to gain of entropy and loss of available energy are consciously neglected here.

This type of vertical instability, with discontinuous change from lower to upper layer, is mainly of theoretical interest. It has its chief value in leading on to the ready calculation of energy from other types of instability.

Energy from Vertical Instability (*continuous linear change*).— is type of vertical instability that is more frequently encountered A that with continuous change of lapse-rate. For example, under strong sunshine a superadiabatic lapse-rate is generated near the surface of the ground. Entropy decreases upwards and therefore the condition is represented on a tephigram by a curve sloping like *AD* (fig. 1). The ideal stabilizing of this condition is attained by each layer seeking its proper entropy level, i.e. by unit particle from *A* moving adiabatically to *C*, unit particle from *D* to *F*, and in fact the lapse-rate *AD* changing to *CF*. Integrating the realizable energy in the same manner as before, we find the total energy to be equivalent to the volume of a pyramid of height $M/2$ upon the base *ACDF*, or $(M/6) \times$ area *ACDF*. Dividing this total energy by *M* we get the average energy per unit mass to be equivalent to 1/6th the area *ACDF*. As a numerical example, consider a layer of depth of a kilometre with a vertical lapse-rate of 12°C., which is 1·23 times the convectively neutral rate; the tephigram tells us that the overturning of the layer can give rise to wind averaging 10 miles an hour. Instability of this type is known to give rise to turbulence and small convection columns.

Energy from Horizontal Instability (discontinuous change).—Suppose that a vessel, with a vertical partition, contains two equal air masses, side by side, each of constant entropy, the values of entropy being S_1 and S_2 respectively, where $S_1 > S_2$; again, there is a frictionless piston of constant weight on top. When the partition is removed, the mass S_1 flows on top of the mass S_2 with release of energy which can be computed graphically as before. But the approximate solution can be seen more readily and immediately by glancing again at fig. 2. Our first example of vertical instability was of the type (*a*). The present example of horizontal instability is (*b*). Both lead (ideally) to the final position (*c*). Now (*b*) is obviously a half-way house in the change from (*a*) to (*c*). So, if the change from (*a*) to (*c*) could release, at the maximum, a kinetic energy per unit mass equivalent to a certain area on the tephigram, then the change from (*b*) to (*c*) will release energy equivalent to one half of that area. To go back to fig. 1, if *AC* and *FD* represent on a tephigram the two air masses lying side by side, the average kinetic energy released when the system passes over to the stable state is 1/8th the area *ACDF*. Expressed in numerical values the velocity that may be generated from two air masses 3 km. high and with 10°C. difference in temperature averages 17·3 m.p.s., while masses 6 km. high with same temperature difference get average velocity of 25·8 m.p.s.

Energy of Horizontal Instability (continuous linear change).—The partition between a hot and a cold air mass, lying alongside one another, may not be and usually is not discontinuous. If the change of potential temperature from the one to the other is continuous and linear, it is again possible to see what the approximate solution must be, when entropy varies horizontally only and not vertically. Let us look at fig. 3. We want to know the energy released in passing from position (*b*) to position (*c*). Now (*b*) is obviously the approximate half-way stage between the vertically unstable position, of superadiabatic lapse-rate, (*a*) and the stable position (*c*). We have seen how to calculate the kinetic energy arising from the change from (*a*) to (*c*). The change from (*b*) to (*c*) must be half that amount. For example, if in fig. 1 the column of air at one end of the continuously changing zone is initially represented by *AC* and at the other end by *DF*, the average change in kinetic energy can amount, at most, to the equivalent of $\frac{1}{2} \times \frac{1}{6} \times$ the area *ACDF* by the time the final stable position is reached. Incidentally this result shows up clearly the limitations of the method. The available energy depends only on the two end values of entropy S_1 and S_2 (fig. 3 *b*), and not on the distance apart of S_1 and S_2. But the actual velocities immediately generated will in fact be very different when S_1 and S_2 are poles apart and when S_1 and S_2 are near together—within a closed system that covers only a few degrees of latitude. In the former, the time factor is overwhelming and turbulence and eddy motion totally prevent any approximation to the velocities calculated in this fashion.



(a) (b) (c)

FIG. 3.

ENERGY FROM LATENT INSTABILITY.

On the tephigram ‘convective instability’ is recognized immediately in any layer from the slope of the wet bulb curve being less steep than a saturated adiabatic or Ś-curve. How such a layer responds to adiabatic lifting in the atmosphere is illustrated on a tephigram. To recognize ‘latent instability’ one must examine the dry bulb curve also; both dry and wet bulb curves must be less steep than, and be cut by, one and the same Ś-curve. For real latent instability the amount of work to be done to a unit particle in order to raise it up first of all to condensation level and beyond to the equilibrium point must be less than the energy gained by it in the succeeding buoyant stage (as illustrated).

To gauge the possible importance of latent instability let us try to estimate, by a brief study of a somewhat extreme example, how much kinetic energy can, at the maximum, be produced by latent instability alone, unassociated with other types of instability. I am going to assume, as our closed system, a column of air with a dry bulb temperature of 100°F at ground level, an adiabatic lapse-rate of temperature up to 8 km. and a large inversion of temperature at that level. The assumption of an adiabatic lapse-rate through so great a depth of atmosphere is an exaggeration that is countered to some extent by the amount of the assumed inversion. In fig. 4, the air temperature is represented by the line *AF* and the inversion by *FE*. Now it is a matter of observation that different air masses with different past histories may have the same air temperatures but different humidities. We can picture one such air mass (e.g. in fig. 4, *AF* and *JF* being the dry and wet bulb curves) with insufficient humidity and without latent instability, in which there is no release of mechanical energy on rearrangement of the air column. Another air mass with the same air temperature may be pictured to have a large amount of latent instability, i.e. with much higher wet bulb temperature in the lower layers (e.g. in fig. 4 *BCGHF*, instead of *JF* may be the wet bulb curve). If the lower half of the mass of air ascends, much cloud and rain is produced, and the rearrangement is accompanied by a great release of kinetic energy. If we imagine the descending air to be unaffected by the falling rain, the maximum energy that may be generated is represented by the volume of a simple solid figure on the base *CEF* (model shown), which when averaged over the whole mass is equivalent to

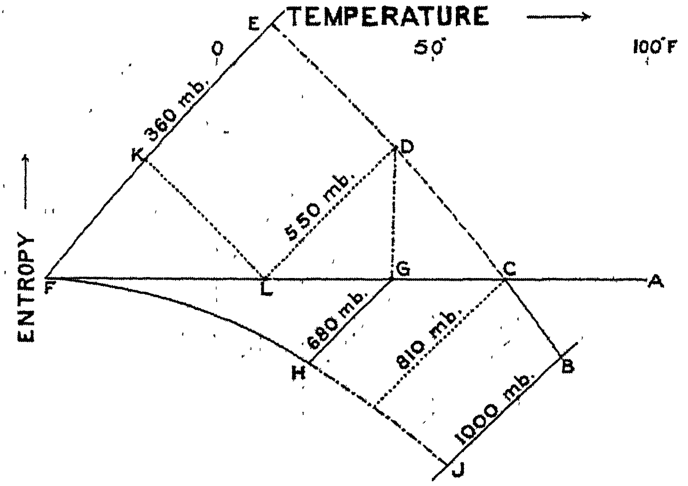


FIG. 4.

a hurricane of 80 miles an hour, the final state being represented on the tephigram by dry bulb curve *EDGA*, wet bulb curve *EDGHJ*. It is a remarkable fact that a change in the lower half of the wet bulb curve alone without any other change at all has raised the theoretically possible wind from zero up to hurricane force. Enormous though that change is, it does not express all the theoretical possibilities of 'latent instability'. In the above calculation the descending air maintains its original water content. Suppose however that, in a manner apparently analogous to, yet in principle different from, the demon of Clerk Maxwell, the spirits or sylphs of the air were clever enough to arrange for each descending unit to take full advantage of the falling rain. Each sylph would be under orders to make the most of but not to transcend the laws of thermodynamics. Each sees its unit of air saturated and cooled to the wet bulb temperature *in situ* before allowing it to begin to fall and then takes care to keep it saturated by rain throughout the descent. Under these conditions the descent takes place along an *S*-curve not along a dry isentropic and the coldness and density of each unit, relative to its environment during descent provide another great source of energy. The final condition is represented by ;—

dry bulb curve—*EDGHJ*. wet bulb curve—*EDGHJ*.

Making a simple calculation on the tephigram (model exhibited)[1] we see that descending saturated air can (in theory) contribute as much to the available energy in this case as the ascending air. That is, the over-turn of the air in the closed system can, if the process is conducted with maximum thermodynamic efficiency, give rise to a wind averaging 115 miles an hour throughout the air column.

The above is an imaginary example and an extreme case. A more practical case may perhaps be illustrated by entering on a tephigram the typical monsoon curves of dry and wet bulb up to 3 km. (using July averages for Poona) and curves of continental air at higher levels (using April averages for Agra). The available energy from this combination suffices to provide an average velocity of 50 miles an hour distributed throughout the whole system, if evaporation from rain is not taken into account, and over 60 miles an hour, if it is. In practice, of course, turbulence, the mixing of air at different temperatures, and other irreversible changes intervene. Even so, it is obvious that we are dealing here with a source of energy in the atmosphere that may suffice to produce as much kinetic energy as is displayed in storms. This source of energy is particularly prevalent in the tropics, where latent heat is more of a reservoir of energy than in temperate latitudes, because of the increase of vapour pressure with temperature. It may be said that this is a very old idea. I agree, but it is one on which we have new light. I think I am right in saying that the fluctuating history of the condensation theory of storms, sometimes in fashion and sometimes out, has been partly due to two facts, first that the exact conditions of storage of latent heat as potentially available energy were not clearly realized before the present decade and secondly because no adequate estimates of the energy realizable within a closed system through the agency of this type of instability alone have, until quite recently, been available.

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[1] The total energy from descending air is represented by an irregular wedge-shaped figure on the base *AFJ*, the top of the wedge being vertically above *GH*.

THUNDERSTORMS AND DUSTSTORMS.

The point that we have just examined regarding the possible release of energy from descending air is of special interest, when we pass on to the application of these quantitative methods to examples of duststorms and thunderstorms. The general tendency in meteorological practice to neglect consideration of the descending air is easily understood, because cloud and rain force special attention upon the ascending air. When however the quantitative examination of energy is attempted, we must treat the thunderstorm or duststorm and its surroundings as a closed system. We must picture to ourselves what happens to the descending air and cannot remain content with the conventional diagram of the 'heat' thunderstorm in which the lowest layers of one kilometre in depth nourish the thunderstorm cloud up to a height of 9 kilometres. As the cloud advances its great capacity continues apparently to be fed from the lowermost layers, but no sufficient compensating down-current is shown. The conventional picture does not show what happens to the great column of air from 1 to 9 kilometres which is displaced by the cloudy air. The downward current that is depicted just behind the roll or squall cloud in the conventional diagram has an origin that is always apparently in the lower portion of the cloud and in essence therefore signifies a return to earth of the air that was originally there. There is a serious difficulty in this. If an original state of instability caused the surface air to rise, it is reasonable to suppose that most of it will tend to remain aloft having moved of its own accord to a level where it will find stability. Also air that travels the cycle up through the cloud and down again to earth should arrive at ground level with its wet bulb temperature unchanged if the cycle is adiabatic, and, in any case, with very little change in wet bulb if the cycle is rapid (as it is in a thunderstorm). Hence the low wet bulb temperatures are not explained by any vortex-like return to earth of surface air, even if it is rain-drenched in the process. Normally, in meteorological theory one is chary of allowing air to descend, unless it is pushed down under the agency of an outside force or at the expense of some available supply of energy. Now quite strong evidence, though not yet complete and overwhelming, has been collected in India recently to show that latent instability is a normal percursor of all 'heat' thunderstorms and duststorms. The tephigram tells us that efficient use of the instability requires an active, self-accelerating downward current, not merely a passive descent. The downward current is one of the most noticeable features in severe thunderstorms and duststorms, bringing with it the strong squally wind of great dust-raising power and sudden drop of temperature just before the rain begins. From what height does that downward current come ? We don't know yet. But all this suggests a somewhat different picture for the ideal, efficient self-propagating thunderstorm, one in which rain-drenched descending winds play their part, as would streams of water of varying temperature debouching from a multi-channelled circuit, the hottest stream from the lowest channel and the coolest on top. We can picture continuity in the stream flow, although the topmost layer finishes below. It may be, of course, that many of the convective storms in nature have no great thermodynamic efficiency. We need much more information with regard to that point from balloon observations. The descending movements certainly need more investigation. The simplest theory to work to, in the absence of further knowledge, is to imagine that low wet bulb temperatures after a storm are carried down by air that descends without change of wet bulb potential temperature (i.e. the wet bulb temperature descends along an *Ś*-curve). The comparatively few observations that are available give heights of anything up to 4 or more kilometres for the level from which air may have descended during thunderstorms. In this way it is possible to explain certain low wet bulb temperatures after storms that cannot be explained by any horizontal advection of air.

If a local heat thunderstorm can develop its own downward current, it can create its own cold wave which acts as the trigger to continue the action in the direction towards which the storm is moving. This type of cold wave is different in origin from that arising from the state of 'horizontal instability' discussed above. It comes from the upper air and is a direct consequence of the initial latent instability.

Several workers in India have been studying the problems of dust- and thunder-storms in recent years, but always one feels the lack of the right observations. We want the observations from a number of places in and around a storm field before, during and after the storm. Unfortunately we cannot control the storm as a physicist controls a laboratory experiment and the *bundobast* needed to get all the necessary special observations is expensive. We have not been able yet to achieve our desire, but even the clearer perception of an objective is a gain.

CYCLONES.

In this city where the word 'cyclone' was first invented and used by Henry Piddington 90 years ago, it is scarcely fitting to close this address without a more specific, even if it must be a brief, mention of tropical cyclonic storms. Piddington, after a training in the Mercantile Marine, became Curator of a Museum in Calcutta and Secretary of the Asiatic Society of Bengal. He seems to have used the word 'cyclone' first of all in his seventeenth memoir on storms, which was published, as all his memoirs were, in the Journal of the Asiatic Society of Bengal. There's a stroke of genius in the suggestiveness of the word 'cyclone'; while his book for mariners about the laws of storms was of great practical value to seamen of all nations. Since Piddington's day many able men have studied the cyclones of the Bay of Bengal, notably H. F. Blanford and J. Eliot, but the essential requirements, or, as the mathematician would say, the necessary and sufficient conditions for the formation of a cyclone still elude us.

The forecaster builds up his impressions from his day-to-day experience. For the development of most, at least, of the major cyclones he is convinced of the importance of the presence of two or more distinct air masses over the Bay. Further, he expects the storm, if it does form, to develop on the zone of partition between two air masses. The partition may not, generally does not, show any sharp discontinuity and may only be a zone of gradual change. Another undoubted item of importance in cyclones is the water vapour, exhibited by the rainfall and by the rapid decay of the storm whenever the rich source of vapour is cut off. The first item suggests horizontal and the latter latent instability as important sources in cyclones, which in a sense takes us no further forward than a century ago, when such theories were first put forward. We may have formed our own opinions but have not yet proved conclusively which is the more important type of instability; we don't know yet whether sufficient latent instability can develop within a single homogeneous air mass to nourish, say, a cyclonic storm of the monsoon type or a cyclone that is transmitted as a depression in the upper air from the China Seas to Indian waters and there re-develops. The final verdict may be towards some reconciliation of the two old opposing theories of condensation and juxtaposition, on the lines that the zone of partition between two air masses is, in favourable conditions, the seat of most intense latent instability [*cf.* the example already cited on p. 15 of latent instability formed by monsoon air below continental air]. Undoubtedly, the energy is sometimes there in great quantities, on and near a partition zone, ready to take part in cyclonic development, if it can be organized. The latter is the side of the problem that the methods of thermodynamics do not touch. How is the release of energy organized into the cyclonic form out of the other form of release, namely, that of local thunderstorms and frequent heavy rainsqualls? The answer to this question will require the application of hydrodynamical as well as thermodynamical methods. To explain European cyclones, the Norwegian meteorologists in recent years have sketched a theory of unstable waves of great wavelength of the order of 1000 km. developing under the forces of gravity and of earth's rotation on a frontal surface separating air masses of different densities. When however latent instability is the main source of energy, the differences of density are less and the same theory may not apply at all or may require to be greatly modified.

To settle the thermodynamical question, we need to be able to measure the humidity of the upper air as accurately as the temperature and then we have to gather upper air observations of temperature and humidity from the shores of the Bay of Bengal, if not from the sea area itself, before, during and after cyclones. Collecting adequate data costs money and at present we must go slowly, but we are ever hopeful that in time we shall have the data and find the solution. The Bay of Bengal, with its cyclones, is ever our challenge.

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SECTION OF CHEMISTRY

President :—S. S. BHATNAGAR, O.B.E., D.Sc., F.Inst.P.

Presidential Address

A SURVEY OF RECENT ADVANCES IN MAGNETISM RELATING TO CHEMISTRY.

I offer my most cordial thanks to the organizers of the Indian Science Congress for electing me President of the Chemistry Section of the Congress in the Jubilee year. It is for the second time that Calcutta has so honoured me and I am deeply conscious of this privilege. An honour like this is in itself an occasion for sincere pride, but it becomes particularly welcome when it comes from Calcutta, the cradle of the still young school of chemistry in India. Its value is further enhanced by the knowledge that I owe my elevation to this position to the self-abnegation of Acharya Sir Praphulla Chandra Ray. It is not for the first time that he has practised this kind of self-denial —his life is, indeed, a long poem in self-sacrifice.

This meeting is a great occasion in the history of the Indian Science Congress, not only because to-day it can look back on twenty-five years of proud and varied achievement, but also because we have to-day in our midst some of the most distinguished scientists of the world including representatives and members of the British Association for the Advancement of Sciences. On your behalf and on my own I extend a most cordial welcome to them. Their presence here to-day proves that in the world of science there are no barriers between the East and the West, that science can transcend racial, political and economic boundaries and that scientists all the world over are a fellowship dedicated to the pursuit of truth, to the service of humanity and to the cause of good friendship.

I am afraid that the subject of my address to-day—A Survey of Recent Advances in Magnetism relating to Chemistry—has only a rather specialized interest. But I have dared talk about this subject only, because I have been deeply interested in it for a number of years. Nor am I a lonely worker in this field. Many investigators all the world over have made this subject their own. Even in our own country there has been no dearth of workers in this field, and without making any invidious distinctions, I may be permitted to mention the names of Raman, Bose, Krishnan, Mata Prasad, K. N.

Mathur, Rai-Chaudhuri and Bhagawantam. In the international field a void has been created by the sad death of Lord Rutherford, as distinguished in the domain of Physics as in that of Chemistry, and with almost superhuman powers of discovering men of genius like Kapitza. Then there are Langevin, Weiss, Gerlach, Van Vleck, Pauling, G. N. Lewis, Stoner, Cabrera and Honda, who have enriched the science of magnetism. Though many of us have not met each other in the flesh, yet there are subtle bonds of common scientific interests between us. It is enough that all of us are workers in the field of magnetism. It is this community of interests that holds so many of us together.

Indeed, it may be claimed with some justification that it was a magnetic instrument that brought the East and the West together for Vasco da Gama, when questioned by his Emperor as to what helped him most in his voyage of exploration to the East, said without a moment's hesitation that it was the magnetic needle that had wrought the miracle.

Since the classification by Faraday[1] of substances into the now well-known ferro-, para- and diamagnetic groups and his classical researches on magneto-optics, the subject of magnetism in relation to chemistry has attracted considerable attention. Perkin[2] in a series of extensive investigations established the intimate relationship between the magneto-optical rotation and chemical constitution, while Curie,[3] Honda and Owen,[4] and Pascal[5] directed their attention particularly to those investigations which involve measurements of the magnetic susceptibility.

Necessarily the developments in magneto-chemistry have to look up to theoretical advances in magnetism for the accurate interpretation of experimental facts. Thus this subject received a fresh orientation when, after the experimental demonstration of the existence of the electrons as the constituents of the atom, Langevin[6] gave a theoretical interpretation of dia- and paramagnetism. He deduced for diamagnetic gram-atomic susceptibility an equation

$$\chi_A = -N\frac{e^2 \cdot \frac{\Sigma\overline{r^2}}{N}}{6mc^2}$$

and for paramagnetic susceptibility $\chi_M = \dfrac{\sigma^2}{3RT}$.

These equations are fundamental, though they apply strictly only to very simple molecules. The temperature independence of diamagnetism and the Curie law follow as simple consequences of the Langevin theory. For paramagnetic substances σ gives the value of the saturation moment $N\mu$ which may be expressed in Weiss units.

Further extensive work on the magneto-chemical measurements, however, led to the conclusion that a large number both of dia- and paramagnetic substances depart considerably from the behaviour predicted by these equations. The susceptibility of many diamagnetics varies with temperature while that of many paramagnetics increases with temperature or is constant. Again, for a considerable number of paramagnetic substances the value of χ_M is not given by Curie's equation $\frac{\sigma^2}{3RT}$ or by the Weiss equation $\frac{\sigma^2}{3R(T-\Delta)}$ for all temperatures, the relation breaking down specially at low temperatures. The agreement between the calculated values on the Langevin equation for diamagnetism and the actual experimental values is less satisfactory when molecules containing a large number of atoms are examined. Empirical correction factors depending upon the number of atoms in the molecule have, for example, to be introduced into the simple Langevin equation for calculating the susceptibility values of electronic isomers.[7]

These and many more difficulties about the behaviour of atoms, molecules, ions and complexes began to multiply as further data became available. A new light was thrown on these problems when on spectroscopic considerations Bohr introduced quantum concepts into the theory of the electronic structure of the atom which finally culminated in the formulation of the quantum theory. In this theory an electron on an orbit can be defined by four quantum numbers, viz. n, the principal quantum number; l, the angular momentum of the electron; m_l, the magnetic quantum number; and ^ms, the spin. The magnetic quantum number m_l represents the component of the angular momentum in the direction of the field applied. This component, which is quantized, has $2l+1$ values. The resolved value of the spin of the electron has the value $\pm\frac{1}{2}$ and is measured in terms of the quantum units $\frac{h}{2\pi}$ of the angular momentum. The electron spinning on its axis is equivalent to a circular current possessing a magnetic moment of $\frac{eh}{4\pi m \cdot c}$ units. For one gramme-molecule this amounts to 5564 gauss × cm. This unit is known as the Bohr magneton and is now universally employed at least in theoretical discussions instead of the empirical Weiss magneton.

It follows that atoms and ions which possess a resultant spin or orbital angular momentum show paramagnetism, and diamagnetism is only found in such atoms as have neither spin nor orbital momentum, i.e. possess only completed shells or sub-shells. The matter is more complicated, though not fundamentally different, in molecules. Here we have to distinguish between two kinds of shells, the 'atomic orbitals' and the 'molecular orbitals'. The atomic orbitals are the inner shells of the atoms participating in the formation of the molecule.

They belong to a particular nucleus and remain practically unaltered, the interaction between those belonging to different nuclei being negligible and that between them and the molecular orbitals being reduced to a mere screening effect. Therefore they are of no account in deciding whether a molecule is paramagnetic or diamagnetic. The molecular orbitals are formed by the valency electrons of the atoms participating in the formation of the molecule which are under the influence of two or more nuclei.

In diatomic molecules the quantum number λ characteristic of those orbitals does not measure the orbital momentum itself, as does l (or L) for atoms, but measures its component in the direction of the molecule axis. The molecular orbitals are complete with 2 or 4 electrons respectively. If a diatomic molecule with an even number of electrons contains only complete orbitals, both spins and λ's are counter-balanced, and it is diamagnetic. If a molecule has an odd number of electrons, at least one orbital is bound to be incomplete, the spins cannot be counter-balanced, and the molecule is paramagnetic. If a diatomic molecule has an even number of electrons, but not complete molecular orbitals (e.g. when an orbital, whose maximal population is 4, contains only 2 electrons), both diamagnetic and paramagnetic configurations are possible, and a consideration of each individual case is necessary to determine whether the ground-state is paramagnetic or diamagnetic.

The matter is still more complicated in polyatomic molecules. This is not the place to deal in detail with this extensive subject, but it may be said briefly that molecules with an even number of electrons and no free valencies are diamagnetic, and that molecules with an odd number of electrons are paramagnetic. Since a free valency is caused by an electron, whose spin is not counter-balanced by that of another electron, and since therefore a free valency is always accompanied by paramagnetism, also such molecules with an even number of electrons are paramagnetic as contain an even number of free valencies, as, for instance, the bi-radicals.

Such considerations led to a rational interpretation of the data which had accumulated on the subject. For example, the values of the magnetic moments of atoms, as observed by Stern-Gerlach technique, received an immediate interpretation. The behaviour of some of the complexes, the Bohr magneton values of rare earth ions, the diamagnetism of rare gases and of a large number of organic compounds and ions of the type $\mathrm{Na}^{\cdot}$, $\mathrm{K}^{\cdot}$, $\mathrm{Sr}^{\cdot\cdot}$, $\mathrm{Ca}^{\cdot\cdot}$, F', Cl', S'', etc. were all satisfactorily explained. The important gaps such as those in connection with the susceptibility results of the ions of the first transition series, which still remained inexplicable on the simpler theory, were gradually filled in, notably by such theories as that of Stoner, who introduced the concept of a crystalline field arising out of the interaction between ions and the surrounding molecules.

A new outlook was given to the subject by the development of wave mechanics. This resulted in a number of attempts to modify and extend the Langevin equations on the new basis, notably by Van Vleck,[8] with a view to the correlation of a wider range of experimental facts.

In the Langevin equation for diamagnetics, the principal difficulty lies in fixing the value of the radius of the electronic orbit, particularly for a complex ion where the nuclear change is rendered much less effective on account of the screening effect of the electrons in lower levels. Pauling,[9] Slater,[10] Stoner,[11] Angus [12] and others have developed theoretical methods for calculating the value of the screening constants, or, more generally, of the charge distributions in atoms and ions, and have obtained satisfactory values for the magnetic susceptibility by introducing the figures into the fundamental equations. These modified equations, however, though in themselves a great advance, fail to give in many cases a completely satisfactory agreement with experimental facts.

Refinements have also been introduced into the Langevin equation for paramagnetics and attempts have been made to explain the feeble paramagnetism independent of temperature exhibited by some substances. According to the views of Van Vleck,[13] paramagnetism in a system is made up of three terms, viz. (*a*) a contribution of the low frequency matrix elements to paramagnetism identical with the Langevin formula and dependent on temperature, (*b*) the contribution of high frequency element to paramagnetism independent of temperature, and (*c*) underlying diamagnetism independent of temperature. This treatment of paramagnetism refers only to atoms with Russell-Saunders (L-S) coupling. For different normal states of the atoms, the angle between L and S would be different, necessitating a different magnetic moment for these states. The theory of Van Vleck is capable of taking these facts into consideration and thus constitutes a distinct advance on the original Langevin hypothesis of a system possessing a permanent moment.

In this necessarily brief and mainly chemical treatment of the subject it is not possible to refer at any great length to the fascinating subject of ferromagnetism which is exhibited by iron, cobalt, nickel and a number of special alloys and steels at ordinary temperatures. A number of attempts, especially by Heisenberg,[14] Bloch,[15] Stoner,[16] Mahajani,[17] Gans,[18] Akulov,[19] Becker,[20] Dorfmann [21] and others have been made to explain this behaviour and are fully described in various text-books. Of special interest to the chemist, however, is the very common, small and approximately constant paramagnetism of metals and alloys which has found interpretation in terms of the properties of collective electrons.

The rapidity with which the subject of magnetism in relation to chemistry has grown, may be judged from the fact that three books[22] on the subject have appeared during the years 1934-35. Even in the short period which has elapsed since the appearance of these books, there has been an almost encyclopædical output of work on magneto-chemical problems. Like any other healthy and growing subject, advances in this field have reacted on the contemporary subjects and the contemporary advances have in turn been responsible for fresh developments in magneto-chemistry. In this survey the subject of magneto-chemistry has been treated under the following heads :—

1. Magnetic moments and nuclear chemistry.
2. Magnetic properties of free atoms and molecules.
3. Magnetic properties of elements.
4. Molecular diamagnetism.
5. Paramagnetism of molecules, free radicals and bi-radicals.
6. Polymerization.
7. Magnetic properties in relation to phase equilibrium.
8. Influence of the magnetic field on homogeneous and heterogeneous equilibria.
9. Catalysis and magnetic properties.
10. Magneto-optical analysis.
11. Photomagnetic effect.

1. MAGNETIC MOMENTS AND NUCLEAR CHEMISTRY.

With the discovery of the neutron and the positron as definite physical entities, Heisenberg's theory of the neutron-proton constitution of the nucleus was put on a firm experimental basis. The older theory of proton-electron constitution of the nucleus had to be rejected on the consideration of (*a*) the application of Bose and Fermi statistics, (*b*) the size of the electron wave function, and (*c*) the impossibility of a potential barrier sufficient to keep the electron inside the nucleus.[23] If both the protons and the neutrons be supposed to have a mechanical spin 1/2, then the resultant of nuclear spins for an atom (protons and neutrons constituting the nucleus) will be integers or half integers, according as whether there is an even or odd number of elementary particles. This conclusion from the vector model of the quantum theory is in accord with the observation. Furthermore, nuclei with mechanical moments will have magnetic moments of the order $\frac{1}{2} \cdot \frac{h}{2\pi} \cdot \frac{e}{m_0 c}$ or $\frac{1}{2} \frac{h}{2\pi} \frac{e}{Mc}$ (where m_0 and M are the masses of the electron and the proton respectively) associated with them according as whether or not there is any electron inside the nucleus. But it has been found that the nuclear magnetic moments are all of the order of $\frac{1}{2}\frac{h}{2\pi}\frac{e}{Mc}$ (usually taken as the unit of nuclear magnetic moment) precluding thereby the possibility of the existence of electrons inside the nucleus. This makes it difficult to explain the emission of the β-particles in the β-ray decay of radio-active elements. This was accounted for by suggesting that electrons are formed just before the β-rays are emitted. In order to avoid the difficulties connected with conservation of energy and angular momentum, a simultaneous emission of a neutrino—a hypothetical particle with no charge and with a mass equal to or less than that of the electron—has been suggested. The neutrino like any elementary particle is assigned a spin 1/2 and the Fermi statistics.[24] Such a particle should have a magnetic moment associated with its spin and as shown by Bethe[25] should produce 100 n^2 ions per kilometre of its path, where n is the magnetic moment in Bohr units. Nahmias[26] investigated the ionization produced by neutrinos shot out from a carefully shielded radio-active source and concluded that the magnetic moment of neutrinos, if at all it exists, is smaller than 1/7000 Bohr unit. It is more probable that the neutrino has no magnetic moment at all and it is useless to search for it by this method.

As has been pointed out, the nuclei have mechanical spins associated with them. A very striking fact is that although heavy atoms are composed of a large number of particles, the greatest value for the spin observed is 9/2 and the majority of values are much smaller. This would be possible, if the neutrons and protons occur in the form of closed shells analogous to the completed electronic groups, so that the spin is contributed by the outermost neutrons and protons only. The problem, though complicated on account of the presence of a large number of particles, becomes on the whole analogous to that of the spin contribution of the electrons in extra-nuclear orbits.

It has been found that with these assumptions it is possible to account for the spin values of the nuclei of atoms of all the four types, viz. with odd and even nuclear charges having odd or even atomic weights.

The theory of closed neutron and proton shells calls for a scheme of distribution of these particles in various levels. White,[27] Gapon and Iwanenko,[28] Bartlett[29] and others have suggested schemes more or less analogous to those for the distribution of electrons in various orbits. According to the latest system of notation first are given the configurations of protons, then those of the neutrons followed by the characteristic level of the nucleus as a whole. According to this scheme the total orbital momentum of the nucleus is denoted by Λ and total spin momentum by Σ whose resultant is the nuclear spin I (total angular momentum of the nucleus). This essentially involves the assumption of Russell-Saunders coupling for the nuclei. Thus a term $(1s^2 2p \, . \, 1s^2 2p^2)^2 P_{3/2}$ signifies 2 and 1 protons in the $1s$ and $2p$ shells and 2 neutrons each in $1s$ and $2p$ shells respectively. The resultant orbital momentum is 1 (P term), the resultant spin 1/2 (doublet term) and the total nuclear moment 3/2. By a complicated process essentially similar to that used in the optical spectra it is possible to calculate the energy of various levels corresponding to a given configuration of protons and neutrons.

The total nuclear spin or the mechanical moment (I) gives rise to the nuclear magnetic moment (μ) and the magnitudes of these two are related to one another by the simple equation: $g \, . \, I = \mu$. The magnetic moment of the nucleus combines with the magnetic field produced by the electrons and with the orbital moment to give rise to the hyperfine structure. The absence of hyperfine structure therefore indicates the absence of a nuclear magnetic moment.[30] This may be due to a small 'g' factor for atoms with a definite integral moment or to a zero spin. A decision on this point may be obtained from the measurement of the alternating intensity of the lines forming the rotational structure of the band spectrum.

Like the mechanical moments, the nuclear magnetic moments also are related to the constitution of the nuclei. Nuclei with both atomic numbers and atomic weights odd have magnetic moment values positive and greater than I, while those having atomic numbers even and atomic weights odd have small and generally negative magnetic moments. Similarly nuclei with atomic numbers odd and atomic weights even have small and positive magnetic moments, while those with both atomic weight and atomic number even have zero values for magnetic moments.

The nuclear mechanical and magnetic moments are thus intimately related to the constitution of the nuclei although it must be admitted that the theory is not yet very much advanced. Experimental determination of these values has also of late attracted considerable attention and the following methods have been developed to determine especially the 'g' value.

(*a*) *Hyperfine structure.*—This method is due to Goudsmit,[31] who has deduced equations showing the relation between donblet separation and 'g' factor, both for penetrating and non-penetrating electronic orbits. This methed has the advantage that it is possible to get the 'g' value and the nuclear magnetic moment both for the normal and excited atoms. It is also possible by this method to get the ratio of the magnetic moments of two isotopes. Its only limitations are the complexities of the patterns and very small separations. Amongst the most successful determinations of magnetic moments in this manner are those for Sc^{45}, Cs^{133} Li^6, Li^7, K^{39}, Na^{23}, Cu isotopes, Sb isotopes, etc.

(*a*) *Polarization of resonance radiation.*—Ellett and Heydenburg [32] have developed a method of determining the hyperfine separations by observing the change in the intensity of the radiation from atoms in a magnetic field. Even if the polarized components cannot be resolved the change in intensity is evident in the polarization of the emitted radiation. By this method very small hyperfine separations for Cs and Na have been determined.

(*c*) *Atomic and molecular beam.*—The original method of Stern and Gerlach[33] of passing a beam of neutral particles through a non-homogeneous magnetic field with a steep gradient and placed at right angles to the path has been modified by Stern, Estermann and Frisch.[34] It has been employed in particular for measuring the magnetic moment of the proton by carrying out experiments with *para-* and *ortho*-hydrogen.[35] The value of 2·5 nuclear magnetons obtained by this method is surprisingly large for the proton but is comparable with the value 2·9 obtained from hyperfine separations.[36] (On Relativity considerations, Wataghin[37] has obtained the value of 3 nuclear magnetons for the proton.) An extremely ingenious modified form of the atomic beam method has been developed by Rabi[38] and employed in the determination of the nuclear moments of the alkali metal atoms.

(*d*) *Other methods.*—(i) The *p*-, *o*-conversion of hydrogen and of deuterium has been found by Farkas and Farkas[39] to be catalyzed by a non-homogeneous magnetic field as provided by an oxygen molecule. From the velocity of conversion of *p*-hydrogen and deuterium into the *o*-variety these authors have deduced the ratio of the nuclear magnetic moments μ_p/μ_D to be $3{\cdot}96 \pm 0{\cdot}11$.

(ii) By passing a beam of particles through two sets of magnetized iron bars used as analyzer and polarizer respectively, and placed at an angle relative to each other, Frisch, Halban and Kosch[40] have developed a method for finding out the direction of precession of the particles under examination. By a slight modification of this method it is possible to determine the sign of the magnetic moment of the neutron which is shown to be negative, as if the particle carried a negative charge. This is in agreement with the indirect value deduced for the neutron from the observed magnetic moments of deuteron and proton.

2. MAGNETIC PROPERTIES OF FREE ATOMS AND MOLECULES.

The earlier work by the atomic beam deflection method on the atomic moments of Zn, Cd, Hg, Pd, Sn, H, Pb, Li, Na, Cu, Ag, Au, Tl, etc. is in entire agreement with theoretical predictions based on spectroscopic grounds. The same applies to the work done during the period under review. Oxygen atoms[41] in an electrodeless discharge yielded a value of 1·67 Bohr magnetons as compared to 1·71 Bohr magnetons deduced from intensity distribution curves. In the case of Bi, Leu[42] obtained an undeflected beam at a temperature of 1183°A, in spite of the ground-state of bismuth being $^4S_{3/2}$. This was attributed to the presence of Bi_2 molecules. At higher temperatures, however, a symmetrical deflection pattern was obtained corresponding to $\mu_B = 0{\cdot}72$. The '*g*' value obtained from the value of the atomic magnetic moment lies between the one calculated for Russell-Saunders coupling and that for *jj* coupling.

The outstanding discrepancy in the earlier work on magnetic moment was for iron, nickel and cobalt atoms.[43] In the case of the first two elements an undeflected pattern was obtained in contradiction to the spectroscopic prediction. Recent careful work by Klabunde and Phipps[44] has, however, shown that the magnetic moment of the iron atom is 2·03 Bohr magnetons and not zero as previously obtained by Gerlach.

The elements of the sixth group of the Periodic Table (Oxygen, Sulphur, Selenium, Tellurium) are particularly interesting, because their diatomic molecules have two valency electrons in an incomplete shell and therefore possess a diamagnetic $^1\Sigma$ and a paramagnetic $^3\Sigma$ state. As to oxygen it has been established for a very long time both by spectroscopic and magnetic evidence, that of the two states mentioned $^3\Sigma$ is the lower one, thus rendering the oxygen gas paramagnetic. Wiersma and Gorter[45] showed that its paramagnetic susceptibility is influenced by pressure, the lower value of χ at higher pressures being probably due to the destruction of paramagnetism on account of the formation of diamagnetic O_4 molecules. The same applies to sulphur, selenium and tellurium in the vapour state. Although their polyatomic molecules are diamagnetic, their diatomic ones have both $^1\Sigma$ and $^3\Sigma$ states. It has been established by spectroscopic evidence that in S_2 vapour also the $^3\Sigma$ state is the lowest one, thus causing it to be paramagnetic. This was confirmed by the magnetic measurements of Néel.[46] There is a chance that in the heavier elements of this group the $^1\Sigma$ level may come below the $^3\Sigma$ level, thus rendering the diatomic vapour diamagnetic. Spectroscopic investigations have so far not been able to bring about a decision, but magnetic measurements carried out at Lahore[47] have shown that Se_2 vapour is paramagnetic and therefore has a $^3\Sigma$ ground-state like O_2 and S_2. Corresponding results on Te_2 are not yet available.

Bromine vapour was examined by Shur and Yanus.[48] Its susceptibility ($-0{\cdot}46 \times 10^{-6}$) is in agreement with the theoretical value.

Based on the measurements of Roth, Gerlach[49] has given the value of the molar susceptibility of argon to be $-19{\cdot}7 \times 10^{-6}$ and shown it to be constant between 290° and 700°C. Mann[50] has also measured the values for the other inert gases, Ne, Kr and X, and found them to be substantially in accord with the theoretical ones.

The molecular states of iodine have been determined in various solvents in the author's laboratories [51] and it has been concluded that while iodine ionizes in carbon disulphide and benzene, it probably continues in the molecular state in *cyclo*-hexane.

3. MAGNETIC PROPERTIES OF ELEMENTS.

Susceptibility of elements en masse.—The magnetic properties of substances in the solid or liquid state differ from those of free molecules in so far as owing to interaction with neighbouring molecules or atoms a structural influence is super-imposed on the molecular magnetism.

In special cases like that of the rare earths it is still possible to draw conclusions regarding magnetic moments from measurements of the solid substance. For instance, the magnetic moments of the atoms of cerium and praseodymium [52] have been obtained by investigating their susceptibility as function of the temperature. Besides these two rare earths, lanthanum, neodymium [53] and gadolinium [54] have also been studied. In some cases the susceptibility appears to be affected by the field strength, presumably on account of ferromagnetic impurities. All of them follow the Curie-Weiss law with the exception of gadolinium and possibly of cerium. Gadolinium is ferromagnetic with a Curie temperature of 16°C., the low temperature saturation moment per atom being greater than that of iron. The behaviour of cerium is still under dispute.

There is, however, one remarkable fact about the rare earths. The magnetic moment of trebly ionized Gd can be theoretically calculated, being 39·26 Weiss magnetons, and is in exact accord with the value 39·28 Weiss magneton measured for the metal. This strange agreement between the atom and its ion is more or less common to all the elements of the rare earth group. Stoner [55] has tried to make this plausible by pointing out that probably the whole of the paramagnetism both of atoms and ions is due to the incomplete $4f$ shell, which is common to either of them, and that the contribution of the 3 valency electrons of the atoms is of minor importance owing to their becoming collective electrons in the metal. Definite proof is still wanting, but this suggestion is so interesting that further investigation appears to be worth while.

Prins [56] and later Coffin [57] examined an amorphous form of antimony, more popularly known as 'explosive antimony'. The latter author reports the value of the susceptibility to be $-0{\cdot}38 \times 10^{-6}$ as compared to $-0{\cdot}88 \times 10^{-6}$ for crystalline antimony. He has also shown that explosive antimony should be regarded as a super-cooled liquid. The non-metallic nature of explosive antimony may, according to Coffin, be due to the change of the metallic bond to the homopolar one.

Bates and Baqi [58] have measured the magnetic susceptibility of chromium over a range of temperature and shown its value to be constant. This is an interesting illustration of paramagnetism being independent of temperature.

Measurements on manganese carried out by Bates and Pantulu [59] indicate that its very high paramagnetism is not to be found in the amorphous variety, thus indicating that high paramagnetism is associated with the crystal structure. Bates, Pantulu and Gibbs [60] have extended this work to the measurement of the magnetic susceptibility of Mn heated to different temperatures in an atmosphere of nitrogen and have found that ferromagnetism is developed in samples, which, as shown by their X-ray spectrum, are in the γ phase and have an enlarged lattice.

The magneto-chemical behaviour of rhenium has also attracted attention. Its specific magnetic susceptibility has been measured by Perrakis and Karatos [61] and found to be $0{\cdot}046\times10^{-6}$ in accord with the value $0{\cdot}040\times10^{-6}$ in the heptavalent state.[62] This agreement, unless due to an experimental error, shows at the same time, that the rhenium compounds chosen by the authors were in a covalent state of combination.

Lane [63] investigated the magnetic behaviour of barium as a function of temperature and showed that its specific magnetic susceptibility increases from $0{\cdot}147\times10^{-6}$ at 20° to $0{\cdot}415\times10^{-6}$ at 400° with a break at 350°, which agrees with the temperature of discontinuity of electric resistance observed by Rinck.[64] This behaviour suggests a change of the crystalline modification, but since it is inconsistent with the results reported before, it should be followed up.

A good deal of controversy still exists regarding the susceptibility of mercury in the liquid state. Honda [65] obtained a value of $-0{\cdot}19\times10^{-6}$, whereas measurements of Bates and Tai [66] yielded a value of $0{\cdot}1676\times10^{-6}$. This is also in agreement with the average value of $-0{\cdot}172\times10^{-6}$ found in the Lahore laboratories [67] for mercury from various sources, but disagrees with the susceptibility of mercury vapour. The vapour was investigated by Shur,[68] who found its susceptibility to be $-0{\cdot}389\times10^{-6}$; theoretical considerations of Slater yielded $-0{\cdot}42\times10^{-6}$. The disagreement between the values for the liquid and the vapour states is probably due to mercury forming polyatomic molecules in the liquid state.

Mention must be made of the work on bismuth, which on account of its abnormal diamagnetism and other magnetic anomalies has been a centre of interest both theoretically and experimentally.

The bismuth crystal has a layer lattice with homopolar linkages within the layers and metallic ones in the direction perpendicular to it and therefore is bound to exhibit certain peculiarities. Goetz and Focke[69] have made extensive investigations on its anomalous diamagnetism, the influence of temperature and the presence of foreign atoms in the lattice. With the help of Bloch's lattice theory, Jones[70] was able to explain the formation of the layer lattice and the anomalies in diamagnetism and magnetostriction. A theory of the magnetostriction of single crystals of Bi was also advanced by Kapitza[71] and formulæ for the magnetostriction of trigonal Bi have been developed by Shoenberg.[72] Kapitza's experimental results[73] on magnetostriction of bismuth have been confirmed by Wolf and Goetz,[74] Goetz and Focke[75] and Shoenberg.[76]

Perhaps the outstanding event in the work on bismuth is the De Haas-Van Alphen Effect. De Haas and van Alphen[77] found that at temperatures 20·4°K and 14·2°K a decrease of magnetization occurred, when the field exceeded 12,500 gauss, if perpendicular to the diagonal axis, and 14,500 gauss, if parallel to it. At higher field strength the magnetization is again normal. Measurements of Shoenberg and Zakiuddin[78] confirmed these results and a theory of the effect has been proposed by Peierls.[79]

Magnetic anisotropy.—An increasing amount of attention has been paid to the exact determination of the values of susceptibilities along different axes in a crystal. It is mainly due to the work of Krishnan[80] and Mrs. Lonsdale[81] that these determinations have been made the basis of an auxiliary method for determining the structure of crystals. Nilakantan[82] has, for example, studied rhombic sulphur and shown that the X-ray plan of a puckered-ring-shaped molecule consisting of 8 atoms and oriented with the plane parallel to the *c*-axis of the crystal is confirmed by the magne-crystalline data. The magnetic data, however, give the inclination of the plane of the ring to the *a*-axis to be about 70° instead of 50° as suggested by X-ray analysis.

Krishnan and his collaborators[83] have also studied the case of graphite and shown that the high diamagnetism, displayed by it in the direction normal to the basal plane and resulting in the high anisotropy, is expected from the characteristic layer lattice structure of the crystal. The weak bond between the successive layers is supposed to be of the metallic type as contrasted with the comparatively stronger homopolar bonds in the plane of the ring. Ganguli[84] has further shown that the high anisotropy of graphite falls considerably when it is oxidized to blue graphite. Presumably this is brought about by the metallic linkage between the layers getting broken and being utilized in fixing up the oxygen. A further stage in oxidation results in the breaking up of covalent links so that the hexagonal network of carbons breaks up into discrete benzene rings.

Use has been made of these observations of Ganguli and of the workers in Lahore[85] in elucidating the nature of the activation of carbon. It has been shown that this process consists in the development on the surface of carbon of graphitic crystals differentially oxidized.

Study of the magnetic properties of single crystals, particularly of bismuth, thallium, lead, tin, mercury and some ferromagnetic metals, has also been made and much valuable information regarding the structure and other physical properties has been obtained.

Magnetic susceptibility and particle size.—A problem which has aroused considerable interest is the influence of particle size on the magnetic susceptibility. Rao [86] observed a decrease in the diamagnetic susceptibility of elements like Bi, Sb and graphite and an increase for others like Sn and Cu. Attention was drawn early by the present author to the fact that the observed effects may be due to surface oxidation, adsorption of gases,[87] etc. or to a change in the microcrystalline structure on colloidalization.[88] From a series of carefully planned experiments involving a rigorous control of the method of preparation of elements, their powdering, grading and chemical examination, it was shown that there is no effect of the particle size on magnetic susceptibility in the case of Bi,[89] Sb,[90] S, Se, Te, Pb, Cu[91] and Sn[92] down to about 0·4μ. Lessheim[93] has discussed the subject at some length and has summarized the experimental evidence available and concluded that the results are in agreement with the author's point of view.

Where chemical changes are excluded the observed changes in magnetic susceptibility have been shown to be due to the change in the microcrystalline structure. Prins [56] has, for example, established that the explosive form of antimony, which is amorphous in nature, has a much lower magnetic susceptibility than the crystalline variety. Measurements on red and yellow oxides of mercury in the author's laboratories [94] showed that the magnetic susceptibility of the two varieties is identical, while the susceptibility values for the red and yellow oxides of lead are different. The structure of the two oxides of mercury has been shown to be identical. The difference in colour arises on account of the difference in the state of aggregation. The two oxides of lead have, on the other hand, a different crystalline arrangement. The magnetic behaviour of the two sets of oxides is thus satisfactorily accounted for.

Rao [95] has recently extended his work and shown that cold-stretching also involves a change in the magnetic susceptibility and concludes that the particle size effect observed by him is analogous to that observed on cold-stretching. It may be pointed out that cold-stretching involves a forcible change or at least severe distortion of the crystal structure. Such an effect should of course involve a change in the magnetic properties.

4. MOLECULAR DIAMAGNETISM.

We shall now refer to molecular diamagnetism, which constitutes perhaps the most important chapter in magnetism in relation to chemistry. As a result of extensive systematic investigations of the magnetic properties of non-polar organic compounds, Pascal discovered the principle of additivity of diamagnetic properties of these substances. The molecular susceptibility χ_M could be closely represented as $\chi_M = \Sigma\chi_A + \lambda$ where $\Sigma\chi_A$ represents the sum of the atomic susceptibilities of all the atoms in the molecule and λ is the constitutive constant depending on the nature of the linkages between the atoms. Thus the effect of double bonds, ring formation or strongly polar groups was generally found to lower the diamagnetism of the whole molecule.

Pascal's values have been shown to be generally fairly accurate, but a critical study of his data shows that a re-examination of his values is necessary, e.g. the value $-11{\cdot}86 \times 10^{-6}$ for the CH_2 group obtained by Pascal from a large number of substances differs considerably from his own value $-11{\cdot}42 \times 10^{-6}$ deduced from nitro compounds. With the aid of the magnetic interference balance, Mitra and Tuli[96] obtained a value of $-11{\cdot}36 \times 10^{-6}$ for the CH_2 group from a study of various homologous series, which is in accord with that of Pascal for compounds with a nitro group. The lower experimental value for CH_2 gives a value $-2{\cdot}68 \times 10^{-6}$ for χ_{H_2}. This value is in better agreement with the theoretical value of $-2{\cdot}37 \times 10^{-6}$ than with the value $-2{\cdot}98 \times 10^{-6}$ which was deduced from Pascal's data.

Gray and Cruickshank[97] have, however, obtained a value of $-11{\cdot}87 \times 10^{-6}$ for the CH_2 group from an investigation of three different homologous series of organic nitrates, nitrites and nitro compounds. The nitrates and nitrites were not studied by other workers as they are difficult to obtain in a pure state. It is evident that owing to developments in the theory a more exact determination of the CH_2 group in various states of combination is desirable.

On the additivity law the susceptibilities of organic isomers would be expected to be identical, but recent measurements[98] have shown that small and definite differences exist between different organic isomers, for example, for aliphatic isomerides, the susceptibility increases in the order: primary, secondary and tertiary; for aromatic isomerides, the ortho forms have the highest susceptibility.

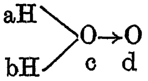
Pascal determined the value of the constitution correction factor λ for a large number of organic compounds. Recently useful addition to this has been made by Kapur and Verma[99] in my laboratories who have determined the λ value for that class of organic compounds known as addition compounds. λ was found to have a specific value for different compounds, which depends on the nature of the various substituents and groups present. Kido[100] has also recently studied the effect on susceptibility of replacing various groups in many compounds.

Whether or not the additivity law of Pascal holds good for polar compounds as well, has been the subject of investigation of various workers during recent years. An extensive study of inorganic compounds by Kido,[101] Flordal,[102] Subramaniam[103] and the work carried out in the writer's laboratory[104] shows that in electrovalent salts, where the ions have complete inert gas configuration, the molecular susceptibility can be considered to be the sum of the ionic susceptibilities which constitute the molecule, but in compounds like $HgCl_2$, CdI_2 the values obtained are slightly higher, and this may be due to their being covalent. Moreover, it has been observed that the susceptibility of an ion in a dissolved state is higher than in the solid state. This deviation is due to the assumption in calculations that neither the solvent nor the solute undergoes any change and the ions behave as perfectly free ions. But from Farquharson's work[105] on acids and from theoretical considerations the higher ionic susceptibility values in solutions have been shown to be due either (*a*) to the deformation of the electronic system of the molecules by the polarizing action of the molecules of the solvent to the extent of producing more dissociation, (*b*) to the formation of polymers, or (*c*) to the depolymerization of the solvent molecule. Thus whenever any of the above-mentioned complications would arise, the ionic susceptibility value would not vary linearly with the concentration. The formation of hydrates and other complexes in solutions can therefore be ascertained by determining the ionic magnetic susceptibility values, and this has been done by a number of workers.

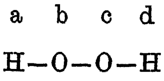
Many attempts have been made during recent years to ascertain the validity of various expressions for atomic or ionic susceptibilities, put forward by Pauling,[9] Van Vleck,[106] Slater[10] and Angus[12] on theoretical considerations. The results obtained in the writer's laboratory showed, in general, that there is a close agreement between experimental ionic susceptibility values and those calculated according to Slater's and Angus's methods.

Several workers have also utilized the plans proposed on quantum mechanical considerations to elucidate the structure of diamagnetic compounds. Varadachari and Subramaniam[107] determined the susceptibilities of a number of sulphur compounds in solution and by comparing them with the values obtained on theoretical considerations assigned different valencies to sulphur in different compounds. Farquharson[108] similarly studied the magnetic behaviour of sulphur trioxide, potassium bisulphate, potassium sulphite, potassium thiosulphate, potassium persulphate, potassium pyrosulphate and potassium tetra-thionate and determined according to Pauling's and Slater's plan the polarity of some of the linkages. Although applied with success to cases where the compound behaved either as a perfect electrovalent or as a covalent one, the various plans for the elucidation of the structure have not so far been successful in cases where there is partial dissociation.

Gray and Cruickshank [97] have put forward a new plan based on that of Pascal, and utilizing Pauling's theoretical results, for studying the structure of diamagnetic molecules. They have calculated the 'depression' of diamagnetism for various bonds in different compounds. The plan is a great advance in the elucidation of structure, because it helps in differentiating between different structures including those involving resonance, and can be applied to cases for which no method has hitherto been available. One of the interesting cases which has been discussed by these authors is that of hydrogen peroxide. Hydrogen peroxide has been commonly assigned structures I and II.



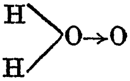
I.



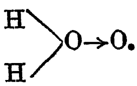
$\overset{a}{H}-\overset{b}{O}-\overset{c}{O}-\overset{d}{H}$

II.

The experimental value for the molecular diamagnetism has been found to be $-16{\cdot}73 \times 10^{-6}$. The values of the structural molecular diamagnetism for the formulæ I and II as calculated on Gray and Cruickshank's plan are 17·75 and 17·55 respectively.

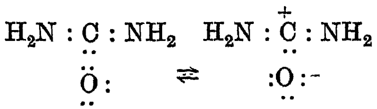
The difference, 1·02, between the calculated molecular diamagnetism for the structure  and the experimental value may be accounted partly to the polymerization and partly to the depression due to co-ordinate bond O→O. The depression for O→O is 0·6 and the remaining 0·42 value can be reasonably ascribed to polymerization. According to the other formula the difference between the calculated and the observed value is 0·82. This structure contains the covalent link O—O which probably gives a depression greater than 2. There would be some depression due to polymerization as well. Thus the difference 0·82 is much less than that which would be due both to the polymerization and to the O—O link.

Accordingly these results clearly give support to the formula :



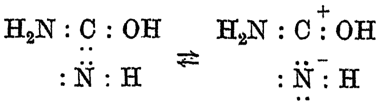
The structures for benzene, naphthalene, acid carboxyl and water assigned on the new plan show close quantitative agreement with the diamagnetic data.

Recently Clow[109] has applied this plan to the study of the much debated structure of urea and its derivatives. Several structures including the simple carbamide and the cyclic structure proposed by Werner[110] have been suggested to account for their various physical and chemical properties. With the introduction of the concept of quantum mechanical resonance Pauling[111] suggested that urea and some of its derivatives should be represented by resonance structure. The carbamide structure can resonate between



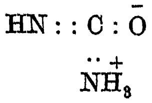
$$\begin{array}{c}\mathrm{H_2N : \underset{\cdot\cdot}{C} : NH_2} \\ \underset{\cdot\cdot}{\ddot{\mathrm{O}}}:\end{array} \rightleftharpoons \begin{array}{c}\mathrm{H_2N : \overset{+}{\underset{\cdot\cdot}{C}} : NH_2} \\ :\underset{\cdot\cdot}{\mathrm{O}}:^-\end{array}$$

while the amino-imino structure presents a second possible type due to resonance in the C : : N group

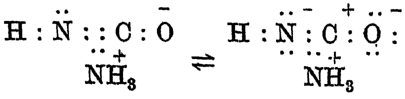


$$\begin{array}{c}\mathrm{H_2N : \underset{\cdot\cdot}{C} : OH} \\ :\ddot{\mathrm{N}}:\mathrm{H}\end{array} \rightleftharpoons \begin{array}{c}\mathrm{H_2N : C \overset{+}{:} OH} \\ :\underset{\cdot\cdot}{\overset{\cdot\cdot\,-}{\mathrm{N}}}:\mathrm{H}\end{array}$$

The cyclic structure proposed by Werner can resonate when represented as ' zwitterion ' or the so-called hybrid ion



$$\begin{array}{c}\mathrm{HN :: C : \overset{-}{O}} \\ \overset{\cdot\cdot\,+}{\mathrm{NH_3}}\end{array}$$



$$\begin{array}{c}\mathrm{H : \ddot{N} :: C : \overset{-}{O}} \\ \overset{\cdot\cdot\,+}{\mathrm{NH_3}}\end{array} \rightleftharpoons \begin{array}{c}\mathrm{H : \underset{\cdot\cdot}{\overset{\cdot\cdot\,-}{N}} : \overset{+}{\underset{\cdot\cdot}{C}} : \underset{\cdot\cdot}{\overset{\cdot\cdot\,-}{O}} :} \\ \overset{+}{\mathrm{NH_3}}\end{array}$$

The calculated resultant magnetic susceptibility for the three possibilities are 27·46, 31·69 and 33·35, respectively, against the experimental value 33·56. It is clear that the resonating ' zwitterion ' formula agrees with the experimental value. This is therefore a strong evidence in favour of the resonating zwitterion which is an extension of the cyclic structure of Werner.

Since the discovery of heavy hydrogen, much interest has been shown in its compounds specially in the measurement of their physical constants. This is all the more so on account of the fact that the compounds of heavy hydrogen have ceased to be chemical curiosities and are entering more and more into the every-day life of the organic and inorganic chemist. One of the most useful additions to the physical data of the subject has been the exact determination of the value of the magnetic susceptibility of heavy water. Some of the most recent and reliable data available at present are tabulated below :

Author.	% of D_2O employed.	$-\chi\times\cdot10^{6}$.
Hoare[112]	99·2	0·648 ±0·004
Selwood and Frost[113] ..	92·0	0·644
Cabrera and Fahlenbrach[114]..	99·0	0·637
Trew and Spencer[115] ..	99·2	0·637 ±0·07
Nehra and Qureshi[116] ..	99·5	0·638

Iskenderian[117] has also recently carried out measurements with D_2O and HDO and found the values for their specific susceptibilities to be $-0{\cdot}6466\times10^{-6}$ and $-0{\cdot}6807\times10^{-6}$ respectively as compared with $-0{\cdot}72\times10^{-6}$ for H_2O. The molecular susceptibilities for D_2O and H_2O on these data are $-12{\cdot}95\pm0{\cdot}01\times10^{-6}$ and $-12{\cdot}97\times10^{-6}$ respectively, which are practically identical.

5. PARAMAGNETISM OF IONS, MOLECULES, FREE RADICALS AND BI-RADICALS.

As regards the paramagnetic molecules, the electronic theory of atomic structure assigns the paramagnetism of an ion

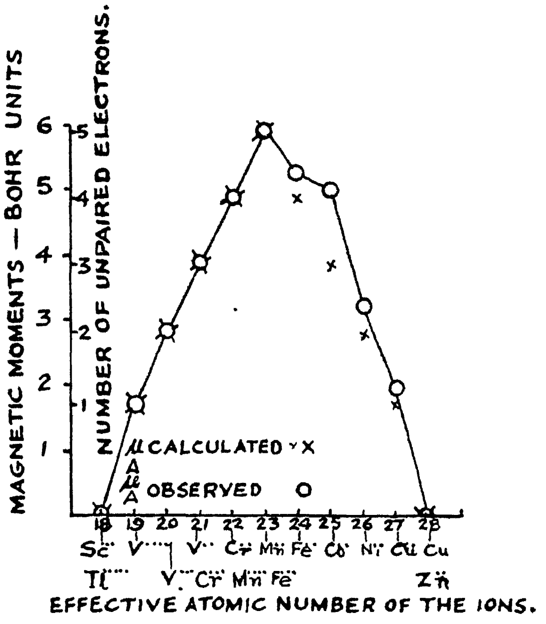


FIG. 1.

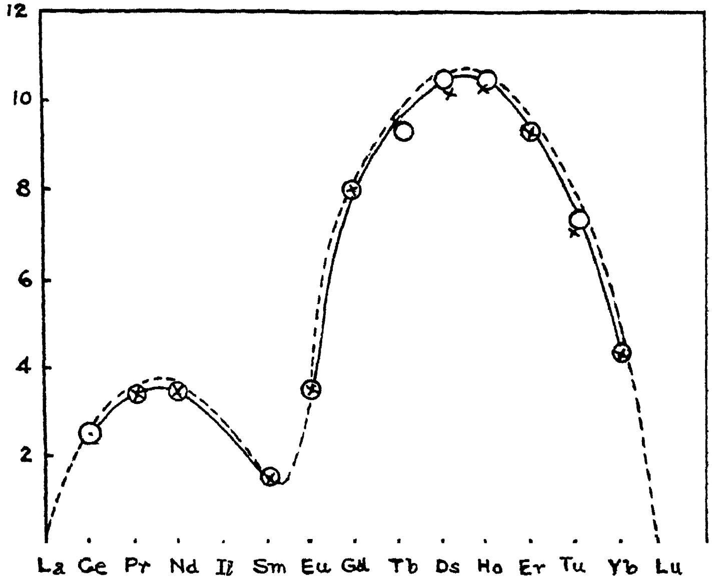
either to the orbital angular momentum of an incomplete electron shell or to its resultant spin. In accordance with this the experimental results have shown that the ions of the transition series and of the rare earths are paramagnetic. The ionic susceptibilities of the elements of the first transitional series are given more or less satisfactorily by the expression

$$P_B = \sqrt{4S(S+1)}$$

according to Bose,[118] Stoner [119] and Van Vleck [120] where $P_B =$ Bohr magneton and S is the resultant spin moment. The resultant orbital moment L is rendered more or less completely inoperative due to strong interaction with the neighbouring ions. The actual experimental values and those calculated on the basis of the above formula are set out graphically against the effective atomic number of the first transition series (Fig. 1).

The first half of the series shows quite good agreement ; the last half, on the other hand, reveals an appreciable deviation, and the moments of the ions in this half extend over a short range suggesting that interaction may take place to different extents in different compounds, and is not strong enough to render the effect of the orbital momentum completely ineffective. Thus the experimental results may give an immediate indication of the existence of interaction effects which may leave the spin free but may partially or totally quench the effect of the orbital moment. In order to investigate this point the magnetic moments of Ni, Co, Mn, Cu ions were determined in the author's laboratories.[121] Most of the salts studied were organic, because they could be obtained in a sufficiently pure state. It was observed that both in the case of Mn and Cu ions the experimental and theoretical values calculated according to the Bose-Stoner formula agreed well, thereby indicating the total quenching of the moment. But in the case of the Ni and Co ions the experimental values obtained varied between 2·75 and 3·2 and 4·97 and 5·37 Bohr magnetons respectively, against the theoretical values of 2·83 and 3·87 respectively. If there is no quenching of the orbital moment, according to the Hund formula : $P_B = \sqrt{4S(S+1)+L(L+1)}$ the values should be 5·20 and 4·47 for Co and Ni ions respectively. The experimental results obtained by the authors are in between the two values calculated by the two different formulæ. The results, therefore, indicate partial quenching of the orbital moment and the different ionic moment values with different salts indicate the extent to which the orbital moment is quenched.

In the case of rare earth ions ($Z = 54$ to $Z = 68$), however, the incomplete electron shell which gives rise to paramagnetism is one of the inner shells. It is, therefore, not subject to the strong interactions with the neighbouring atoms as is the unfilled shell of the transition elements. Consequently, the contribution due to the orbital angular momentum to the paramagnetism of the ions is not annulled and must theoretically be taken into account in the magnetic moment. The older values available for the ionic moments of rare earths, because of their doubtful purity, did not agree well with the theoretical values calculated according to the Hund method. The values obtained during recent years,[122] however, agree closely with the calculated values. This agreement is brought out clearly in Fig. 2 where the experimental and calculated values (according to Hund) have been plotted against the effective atomic number of rare earth ions.



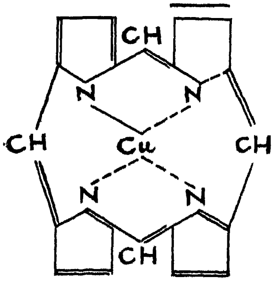
EFFECTIVE MAGNETIC MOMENTS OF RARE EARTH IONS. THE BROKEN CURVE REPRESENTS THE THEORETICAL HUND-VAN VLECK CURVE.

Fig. 2.

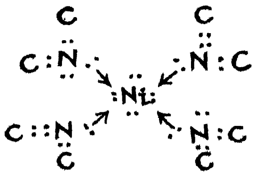
The ions of the transition metals of the first series have been found to be paramagnetic, but the complex salts formed by them are diamagnetic, indicating that during the process of co-ordination the unpaired electrons of the outer shells become paired and thus acquire an inert gas configuration, thereby destroying completely the momentum of the ion. Where the inert gas configuration is not acquired the ion exhibits paramagnetism corresponding to the number of unpaired electrons. Thus by investigating the magnetic properties of these complex compounds much valuable information regarding the nature of various linkages has been brought to light. The theory, however, has several snags and requires a more fundamental physical basis. By such determinations a true complex formation has been distinguished from a more obscure double salt formation. The ionic magnetic moment of Cu in $CuSO_4(NH_3)_4$ and other copper complex salts [47] was found in author's laboratories to be 1·89, exactly the same as that of a Cu ion in an electrovalent salt, against the zero magneton value obtained for tetrakisethylene thiocarbamide copper nitrate.[123] It is therefore to be concluded that in the copper-ammonium complex the various constituents are held together by electrovalent forces, whereas in the other true complex salt the constituents, which go to form the complex, actually share the electrons with the central atom.

Of some general interest during recent years has been the application of this method to the elucidation of the structure of the constituents of blood.

Klemm [124] was the first to investigate the magnetic properties of porphyrin complexes, which form the basis of a number of natural products including blood. The metal complexes of porphyrin derivatives were found to be diamagnetic. If there were a salt-like combination between the metal and porphyrin, the metal complex would be paramagnetic, but because it is diamagnetic, it has to be regarded as a true complex and has been assigned the structure No. 1. On the electronic basis the structure is represented by diagram No. 2. Working



No. 1.



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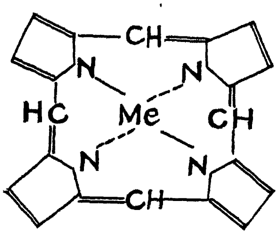

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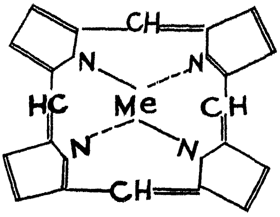


No. 4.

independently, however, Haurowitz[125] found that Ni compounds of porphyrins are paramagnetic and hence concluded that the union of the metal atoms occurs by loss of 2 electrons to the organic group. From the consideration of other properties, such as molecular volume, X-ray spectrum and solubility as well, they have assigned the structure 3 to the metal complexes in preference to 1 and 4. This controversy about the magnetic properties of Ni porphyrin complexes has been closed, since the joint publication of Haurowitz and Klemm,[126] who have recently collaborated and reported that the differences observed by them are not real. They have found the nickel salt of dimethyl mesoporphyrin to be about as diamagnetic as the parent porphyrin itself, and the nickel salt of tetramethyl hematoporphyrin, which was previously reported to be paramagnetic, becomes also diamagnetic on ageing, and have concluded that Ni porphyrins contain no unpaired electrons.

These conclusions have recently been supported from a study of the magnetic properties of the constituents of hemoglobin by Pauling and Coryell.[127] The authors report that globin hemochromogen, dicyanide hemochromogen, nicotine hemochromogen, pyridine hemochromogen and Ni protoporphyrin are diamagnetic and ferriheme and ferroheme are paramagnetic showing magnetic moments of 5·69–5·93 and 5·02–4·83 Bohr magnetons respectively. These magnetic measurements correspond to five unpaired electrons for ferriheme, four for ferroheme and zero for the rest. The presence of unpaired electrons in ferri- and ferrohemes indicates therefore that the iron atom is attached to the four adjacent nitrogen atoms of the porphyrin not by covalent bonds but by ionic bonds. On the other hand the presence of no unpaired electrons in the other four hemochromogens indicates that the 3d orbitals of the ferrous iron atom are involved in the formation of covalent bonds and that the iron atom is accordingly attached by essentially covalent bonds not only to the four porphyrin nitrogen atoms but also to two other atoms giving an octahedral arrangement of six atoms about the iron atom. Continuing their investigations on hemoglobin, oxyhemoglobin and carbon monoxyhemoglobin Pauling and his collaborators[128] have studied the magnetic properties of ferro-hemoglobin and hydroxide, hydrosulphide, fluoride and cyanide of ferrihemoglobin. Both the oxy- and carbon monoxyhemoglobin are found to be diamagnetic and hence to have no unpaired electron indicating that the ferrous iron atom is involved in the formation of six octahedral covalent bonds, four to the porphyrin nitrogen atoms, one to an atom (probably nitrogen) of the globin and one to the carbon monoxide in case of carbonmonoxy and to the oxygen in the case of oxyhemoglobin. The magnetic susceptibility of ferrohemoglobin corresponds to an effective magnetic moment of 5·46 Bohr magneton, of ferrihemoglobin to 5·80, of ferrihemoglobin fluoride to 5·92, of ferrihemoglobin hydroxide to 4·47 and of ferrihemoglobin hydrosulphide and cyanide to 2·26 and 2·50 respectively. The magneton values for ferrihemoglobin cyanide and hydrosulphide correspond to one unpaired electron per heme, indicating essentially covalent bonds; for ferrihemoglobin and its fluoride to 5 and for ferro to 4 indicating essentially ionic bonds; and for the hydroxide to three indicating bonds of an intermediate type.

It would not be out of place to mention here that over ninety years ago Faraday investigated the magnetic properties of dried blood and made a note 'Must try fresh blood'. Had he then determined the susceptibilities of oxygenated and deoxygenated blood he would have found, as Pauling and his collaborators have, a considerable difference and the subsequent researches on blood and hemoglobin would have been considerably influenced by that observation.

Hemmett and Walden [129] as a result of similar magnetic measurements carried out on phenanthroline ferric complexes determined the nature of linkage of the Fe atom with the rest of the phenanthroline molecule. They concluded that because the atomic susceptibility of the Fe atom in the blue complex having the formula $Fe(C_{12}H_8N_2)_3^{+++}$ was found to be 2446×10^{-6} practically identical with the value observed with the ferricyanide ion, the Fe atom was co-ordinately linked. In the brown complex $[Fe(C_{12}H_8N_2)_2(H_2O)OH]Cl_2$, however, they suggested that the Fe atoms were so orientated in the molecular grouping that the electronic moments were neutralized and thus accounted for the low atomic susceptibility value observed.

Klemm and his collaborators [130] have employed this method extensively to distinguish between the true and the loose complexes formed by the metals of the transition group of the first series. They could not, however, apply with much success this method to the complexes of the higher members of the transition series, i.e. of Mo, W and Re.[131] In the following Table the experimental and calculated magneton values for some of the complex compounds of the higher transition period are given.

Name.	MAGNETON VALUES.		
	Determined.	Calculated	
		Hund.	Bose.
$Rb(ReCl_4)$ ..	0·4	0·0	4·9
$K_3(MoCl_6)$ ..	3·7	0·8	3·9
$K_2(ReOCl_5)$ ..	0·5	1·6	2·8
$K_4Mo(CN_6)$ ..	0·0	1·6	2·8

The experimental results do not agree either with the values calculated according to the Bose-Stoner formula or with those calculated according to Hund's method. As the ions of these metals are larger than those of the Fe group, the interaction with the neighbours will be less and will therefore result in an incomplete quenching of the orbital moment, so, the Bose-Stoner formula fails to give satisfactory results. Hund's method fails because the paramagnetism in these metals is due to the outer electrons, whereas the method is applicable to cases like that of the rare earths, where the paramagnetism is due to the incomplete inner shells. Klemm, however, has concluded from his investigations that it would be possible to distinguish between the different linkages in the complex compounds of the higher transition groups, if it is assumed that when the central atom has a smaller volume and a higher electric charge, the interactions of its electronic orbits with neighbouring atoms are greater.

The magnetic properties have been ingeniously employed to decide controversies regarding structures in many complexes. Spacu[132] considered the yellow α form and the black β form of ferrous tetrapyridine dithiocyanate to be stereoisomers, whereas Rosenheim[133] postulated the β form to be identical with the compound $Fe_3(C_5H_5N)_{10}(SCN)_8$. Asmussen,[134] from a study of the magnetic susceptibility of these compounds showed that α and β forms were well-defined compounds and the magnetic susceptibility value of the β form was quite different from that of $Fe_3(C_5H_5N)_{10}(SCN)_8$, thus proving Rosenheim's view to be incorrect.

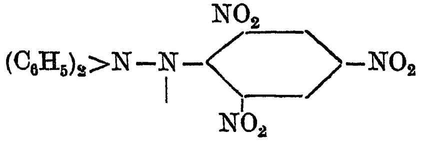
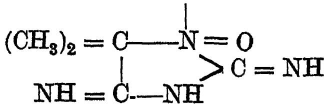
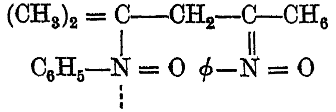
Two varieties of perchromates, red and blue, are known to exist. Schwarz[135] as a result of chemical investigations concluded that Cr in both the varieties is hexavalent. Klemm and Werth[136] determined the magnetic susceptibilities of the two varieties and on comparing the experimental and theoretical values concluded that Cr in the red variety is pentavalent, whereas it is hexavalent in the blue variety. Schwarz,[137] on re-investigating the problem, also arrived at the same conclusion.

Study of paramagnetic substances in solution.—A study of the magnetic properties of solutions of the salts of the transition series has thrown much light on the nature of physical and chemical changes that take place during the process of solution. For some ions in solution, the ionic susceptibility is remarkably constant and the ionic moment both in the dissolved and solid states is the same, as was found by the present author in the case of various Mn salts[138]; for others it varies with the concentration and is modified by the addition of an acid.[139] The striking colour changes of cobalt salt solution from red to blue have drawn much interest. Besides hydration, ionic and double salt formation theories have been employed to explain their behaviour. The study of the magnetic properties of these salts by the workers at the University Chemical Laboratories, Lahore,[140] confirmed the view that complex ions of the type $CoCl_3$ and $CoCl_4$ are formed.

The formation of complex ions of cobalt in bispyridyl cobaltous chloride has recently been suggested by Sugden and Barkworth [141] in the course of an investigation on the magnetism of cobalt compounds. They found that the stable violet form gave at room temperature $\mu_{eff} = 5{\cdot}34$ Bohr magnetons and that the unstable blue form gave $\mu_{eff} = 4{\cdot}62$. On standing for some days the blue variety changed into the violet one and the magnetic moment value also increased to 5·3 Bohr units. This figure which is higher than 3·87 Bohr magnetons—the value of the electron spin for the Co^{++} ion—appears to be due to the conservation of some orbital momentum of the ion. From these and other theoretical considerations, therefore, they have suggested an ionized structure $(Co_4Py)^{++}(CoCl_4)^{--}$ for the violet form and an unionized structure (Co_2PyCl_2) for the blue form.

Free and Bi-radicals.—Magnetic measurements have also yielded valuable information regarding the existence of 'free radicals', which have been defined as substances the molecules of which contain an odd number of electrons. In molecules containing an odd number of electrons, as in ions, there is necessarily a resultant spin moment which will give rise to paramagnetism. If this moment is due to spin only (any orbital moment being quenched) theoretically the value of μ_B calculated from $2{\cdot}84\sqrt{\chi_M(T-\theta)}$ would be 1·73 units. This has been shown to be valid for NO (15 electrons), NO_2 (23), ClO_2 (33) and Clo_3(41).[142] The feasibility of this principle has been abundantly proved recently by Sugden and Müller. Compounds, such as triphenyl-methyl having the molecule of the free radical form $(C_6H_5)_3C$ containing trivalent carbon, have one unpaired electron. Therefore a completely dissociated $[(C_6H_5)_3C]_2$ molecule should have a magnetic moment of 1·73 Bohr magneton. Sugden [143] studied a number of such compounds (No. 1–5) and found that they were strongly paramagnetic but with an effective magnetic moment, rather less than the calculated one. This discrepancy was attributed to the presence of diamagnetic undissociated molecules. In contrast to these in compounds No. 7–11 studied by Müller and his collaborators [144] the experimental value agrees with the theoretical one.

	Substance.	μ_B *observed.*
1.	α-naphthyldiphenyl methyl	1·15
2.	$(p\text{-}NO_2 . C_6H_4)_3C^-$	1·36
3.	Benzoquinone potassium $(C_6H_5)_2 = \overset{|}{C}-OK$ ..	1·45
4.	Phenyl-*p*-diphenylyl potassium	1·58

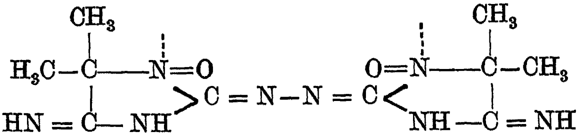
	Substance.	μ_B *observed.*
5.	$Ph_2N\,.\,\underset{\vert}{N}\,.\,C_6H_2(NO_2)_3$	1·61
6.	$(C_6H_5-C_6H_4)_3\equiv C^-$	1·75
7.	Di-*p*-anisyl-N-oxyl $(CH_3O-C_6H_4)_2=\overset{\vert}{N}=O$ ..	1·71
8.	α-α-diphenyl-β-trinitrophenylhydracyl  ..	1·74
9.	 $\begin{array}{l}(CH_3)_2=C\text{——}\overset{\vert}{N}=O\\ \qquad\qquad\;\vert\qquad\quad\; >C=NH\\ \quad NH=C\text{——}NH\end{array}$	1·76
10.	 $\begin{array}{l}(CH_3)_2=C\text{——}CH_2\text{——}C\text{——}CH_6\\ \qquad\qquad\;\vert\qquad\qquad\;\Vert\\ \quad C_6H_5\text{—}\underset{\vdots}{N}=O\;\;\phi-N=O\end{array}$	1·76
11.	Pentaphenyl-cyclopentadienyl	1·72

The corresponding dimeric molecules of these free radicals are, however, diamagnetic. The magnetic method, therefore, may be conveniently used to determine the degree of dissociation of such compounds. There are many other usual methods such as depression of the freezing point, elevation of the boiling point and the more accurate optical method recently developed by Ziegler and Ewald.[145] But these methods cannot be employed with any great degree of accuracy to substances like $C_2(C_6H_5)_6$, which decompose into free radicals, or such as are solid at ordinary temperatures. Müller determined the degree of dissociation of $C_2(C_6H_5)_6$ by the magnetic method, and the results were in very good agreement with those obtained by the optical method. Similarly the degree of dissociation of hexa-aryl substituted ethane has been determined by Müller.[146] The degree of dissociation (2·71) determined by the magnetic method was found to be in close agreement with the value 2·80 obtained by the optical method. Recently Farquharson[142] has determined the degree of dissociation of Cl_2O_6 both in the liquid and the solid states by magnetic measurements.

This method has its limitations. It can be used conveniently for those compounds which can be obtained in a pure state and have a high dissociation constant.

Furthermore, it would be possible with the help of magnetic measurements to prove the existence of bi-radicals, i.e. such substances as have two free linkages due to two unlinked electrons which do not interact with each other. The spins of the free electrons should not compensate each other, and at room temperature ought to have an effective magnetic moment of 1·73 for each half of the molecule.

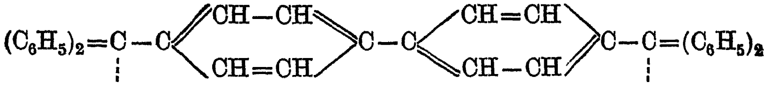
Many compounds, which on account of their colour and other properties have been supposed to be bi-radicals, have been magnetically examined, but till now only two such bi-radicals have been shown to be capable of existence. Porphyrindine is a bi-radical containing two unsaturated N atoms. Its experimental susceptibility value agrees well with the theoretical one.



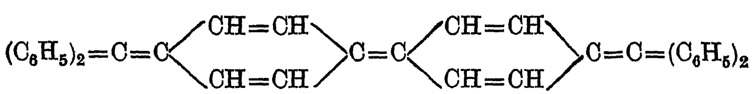
Porphyrindine.

Müller[147] found that *m-m′*-diphenylene-bisdiphenyl-methyl in the solid state and in solution at room temperature existed as an associated diamagnetic double molecule. At high temperatures, however, the deepening of the colour and the paramagnetism proved the presence of a bi-radical.

On account of the strong colour developed and of great reacting power, it had been tendency to formulate such compounds as bi-radicals. A hydrocarbon, discovered by Tschitschibabin,[148] which exhibited great attraction for oxygen and was deeply coloured, was assigned formula I in preference to *p*-quinonoid formula II.



I.



II.

The magnetic investigation by Müller[149] showed that paramagnetism corresponding to I was absent. Similarly Müller had shown from the magnetic measurement of triphenyl α-naphthylquinodimethane that the quinonoid structure should be preferred to the structure assigned by Allard.[150] Enderlin[151] from magnetic determinations showed that rubene derivatives do not exist as bi-radicals under ordinary conditions. They also showed that in a dissociable oxide of tetraphenyl rubene oxygen though easily removable does not exhibit paramagnetism.

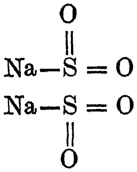
Müller and Sugden have studied a number of compounds which are supposed to be bi-radicals. Müller, however, concluded from magnetic measurements that if the bi-radicals do exist, they are no more than 2%. If the method for magnetic measurements can be developed so that χ of the solution is obtained with an accuracy of 1 per 1,000, it would be possible to prove definitely the absence or existence of bi-radicals.

Sugden[152] recently observed that thiobenzophenone, which from its chemical and physical characteristics has been supposed to be a bi-radical, is diamagnetic. Therefore, he suggested that probably the spins of the two free electrons are opposed to each other resulting in the destruction of paramagnetism and concluded that the magnetic test is not a decisive one for bi-radicals. This view is, however, open to the objection that the word bi-radical has recently been exclusively applied to those molecules which have two free valencies independent of one another.

Since it has been established that 'odd' molecules are invariably paramagnetic, the magnetic method has been used to elucidate the electronic structure of compounds and also to decide in other cases, whether those compounds should be represented by a simple or a double formula.

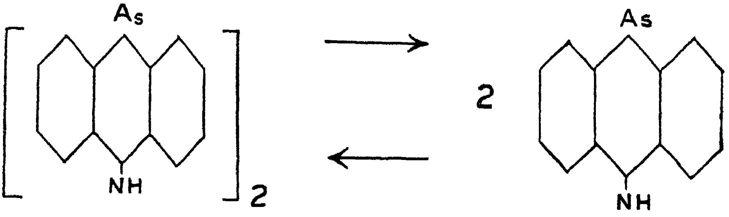
Lowry[153] assumed the existence of single electron linkage in Me_2TeX_2, where X is Cl, Br or NO_3. These compounds were, however, found to be diamagnetic. If these compounds do contain single electron bonds, then there should be a paramagnetic effect due to unpaired electrons. Actually this effect would be masked by the diamagnetic effect of the rest of the molecule. Since, however, diamagnetism is independent of temperature and paramagnetism is affected by it, any masked paramagnetic effect would be shown by a variation of χ with the temperature. Investigations carried out in the author's laboratories[154] showed that the values of χ of these compounds are independent of temperature. Further assuming all the bonds to be electron pairs, the calculated values according to Pascal have been shown by the author to agree well with the observed values. Therefore, it has been concluded that there is no evidence of the existence of single electron bonds in such compounds. Similarly Mulliken[155] had to suggest another electron configuration for B_2H_6 to account for its diamagnetic character. By a similar investigation Elliot[156] elucidated the structure of triple salts, e.g. $Cs_2AgAuCl_6$ and $Cs_2AuAuCl_6$.

It has been debated whether the salts of hyposulphurous acid should be represented as RSO_2 or $R_2S_2O_4$, where R is the metallic radical. Meyer[157] from the study of various physical properties concluded that the sodium salt should be represented as $Na_2S_2O_4$. If the formula is $NaSO_2$, sodium hyposulphite would be paramagnetic, whereas the double formula $Na_2S_2O_4$ represents a diamagnetic molecule. Recent experiments of Klemm[158] showed that this substance is diamagnetic and thus gave a decision in favour of the structure :



$$\begin{array}{c} O \\ \| \\ Na-S=O \\ Na-S=O \\ \| \\ O \end{array}$$

Sugden[159] from similar investigations represented hypophosphorous acid as $H_4P_2O_6$; Klemm[160] represented a compound formed by the interaction of alkali metal and B_2F_6 as $K_2B_2F_6$ and not KBF_3 ; Elliot[161] represented the double salt ammonium hexabromo hypoantimoniate as $(NH_4)_4Sb^{\cdot\cdot\cdot}Sb^{\cdot\cdot\cdot\cdot\cdot}Br_{12}$ containing tri and pentavalent Sb and not as $(NH_4)_2SbBr_6$ with quadrivalent Sb in which case it would have been paramagnetic. Similarly Sugden[152] found 10 : 10′-bis 5 : 10-dihydrophenarsazine to be diamagnetic and assigned to it the formula I in spite of its colour and reactivity which may suggest formula II.



6. POLYMERIZATION.

Valuable information on the question of polymerization can also be obtained by the magnetic methods. Not long ago these methods were restricted in their application to paramagnetic molecules only, which on polymerization became diamagnetic. More recently it has been possible to extend these methods to include the treatment of diamagnetic molecules which polymerize. Where n molecules would polymerize to form the polymer nA, the general expression for the molecular susceptibility of the polymer will be

$$\chi_A = n\chi_A + (n-1)\lambda$$

where χ_A is molecular susceptibility of the molecule A and λ is the constitutive constant arising from the new chemical bond, and the mass susceptibility of nA would be

$$\frac{n\chi_A + (n-1)\lambda}{nM_A}$$

where M_A is the molecular weight of the simple molecule A. In this expression χ_A, M_A and λ are constant and the curve for the change in the mass susceptibility with the number of simple molecules in the complex will, therefore, be a hyperbola. λ is given by Pascal's results so that by measuring the mass susceptibility, it should be possible to calculate n.

Farquharson[162] has studied the polymerization of dimethyl butadiene and cyclopentadiene and confirmed that polymerization gives rise to a change in diamagnetic susceptibility and that, as polymerization proceeds, the mass susceptibility follows a curve, which in the normal case is a hyperbola. Change in mass susceptibility on polymerization was also observed by the present author[163] in anthracene, acetone, benzaldehyde, furfurol and acetyl cyanide.

Farquharson[164] has employed the magnetic data of polyoxymethylenes, the polymerized products of oxymethylene diacetates to determine the -CH_2O-groups in α and β polyoxymethylenes.

These magnetic measurements of polymerized compounds would help us to follow the course of polymerization and in certain cases may be useful in calculating the degree of polymerization.

7. MAGNETIC PROPERTIES IN RELATION TO PHASE EQUILIBRIUM.

Magnetic susceptibility measurements have been frequently used in the study of phase rule equilibria, because, as a result of extensive study of the magnetic properties of various systems, certain rules which provide very useful information regarding structure, formation of intermediate compounds, etc. have been formulated. For example, it is concluded that in the case of solid solutions the susceptibility-concentration curve is a curved line, in the case of mechanical mixture of the constituents the curve is a straight line, whilst the appearance of a new phase indicating the formation of a compound brings about an abrupt change in the slope of the curve. These generalizations have been used by numerous investigators in the study of alloys. Svensson[165] thus studied the Pd-H system and from the analogy of the susceptibility-concentration curve with that of Pd-Ag system concluded that in this system several PdH-Pd alloys are formed. From similar investigations Stephens and Evans[166] have recently shown that the formation of a compound Ag_3Sb at 73% is indicated in the system Ag-Sb, but no such compound formation is indicated in the Ag-Bi, Ag-Pb systems. Fallot[167] has studied the magnetic properties of several alloys of Fe with Al, Si, Cr, V, Au and Sn. He found singular points in the curves, corresponding to modifications or 'superstructures' which were found by X-ray studies, and along with these he found other singular points indicating the presence of other 'superstructures' which had not been detected by X-rays, either because the concentration of the foreign atoms was too low or because their atomic masses were too near to that of Fe. He has thus suggested the study of magnetic properties of alloys as an exceedingly sensitive means for detecting these superstructures.

It is remarkable that, although the alloys of almost every metal have been so extensively investigated, the systematic survey of the magnetic properties of amalgams has not attracted attention till recently. The present writer[168] found that dilute amalgams of copper are merely mechanical mixtures of the two metals in which the value of the magnetic susceptibility varies from that of pure mercury to that of pure copper. Recently Bates and Tai[169] have studied the magnetic properties of a series of amalgams of various concentrations of Mn, Bi, Cr and Cu and found that with the exception of copper all the metals which are diamagnetic in the solid state become paramagnetic in dilute amalgams. The paramagnetism of the metals in amalgams may be suggested to be due to their being in the atomic state, but to establish it a study of their thermomagnetic behaviour would be desirable.

A rather interesting development in this field has been the study of magnetic moments of elements when alloyed with different metals. Gustafsson[170] has recently determined the atomic moment of Mn when alloyed with Cu, Ag and Au and obtained in infinitely dilute solutions a value of 4·8 Bohr magneton in Cu, 5·5 in Ag and 5·4 in Au. The low value for Cu solution is attributed to the small atomic volume of copper. Fallot has employed this method to determine the atomic moment of Fe when alloyed with Pt, Si, Al, Cr, Au and Sn and found that in general an average moment of 11·00 or less occurs in series with elements of lower atomic number than Fe, while values of 11·00 or more are found in the series of alloys with elements of higher atomic number. It has been shown by Stoner[171] that many of the salient facts about the variations of atomic moment in ferromagnetic alloys are readily explained on the basis of a collective electron treatment of ferromagnetism, which is being actively developed by Slater,[173] Mott,[172] Stoner[174] and others.

Not only in alloys, but also in compounds the magnetic susceptibility has been studied in relation to phase rule equilibria. The present author[175] examined the magnetic properties of solid solutions of $KMnO_4$,-$KClO_4$, KCl-NaCl, KBr-KCl and KBr-NaBr and found that in the system $KClO_4$—$KMnO_4$ the susceptibility-concentration curve is a straight line, while the other systems yield curved graphs. The abrupt change of slope in the susceptibility-concentration curve has been recently made use of by Haraldsen and his collaborators, particularly in the study of such systems in which one compound is diamagnetic, while another is para- or ferromagnetic. Haraldsen[176] found that the addition of S to CoS does not bring about any change in the magnetic susceptibility until the composition $CoS_{1\cdot13}$ is attained. At this point, saturation of the mixed crystal series is reached and a new strongly paramagnetic phase (CoS_2) appears, forming a two-phase system between the composition limits $CoS_{1\cdot13}$ CoS_2. Similar observations have been made by Haraldsen and Neuber[177] in the case of the system Cr-S in which the considerable increase in magnetism takes place at a concentration corresponding to $CrS_{1\cdot175}$. This behaviour of Co and Cr is analogous to that of the Fe pyrites, which shows a maximum in magnetization at $FeS_{1\cdot12}$.

8. INFLUENCE OF THE MAGNETIC FIELD ON HOMOGENEOUS AND HETEROGENEOUS EQUILIBRIA.

Although not much attention has been bestowed upon the study of the influence of the magnetic field on the rate of crystallization, electrolysis, conductivity of gases, coefficient of viscosity, etc. during recent years, investigation of these subjects is sure to lead to important developments in magneto-chemistry. Of particular interest is the work of Steacie and Stevens,[178] who observed that a field of 5,000 gauss had no effect on the linear crystallization of $Na_2S_2O_3 . 5H_2O$, whereas a slightly increased rate was observed with $NiSO_4 . 6H_2O$. Senftleben and his fellow-workers[179] have reported a definite diminution of the thermal conductivity of oxygen in the magnetic field. Because of the close relationship between diffusion and thermal conductivity Engelhardt and Sack[180] investigated the effect of the magnetic field on the coefficient of viscosity of oxygen and observed definite diminution of it. Similar results have been reported recently by Trautz and Fröschel.[181] Raha and Chatterjee[182] have extended these investigations to liquids and found that liquids with long chain aliphatic molecules, i.e. acetone and propyl alcohol show diminution, liquids of the aromatic class, i.e. nitrobenzene, toluene and isoamyl alcohol show increase, and carbon tetrachloride and cerium nitrate solutions show no change in the magnetic field.

The magnetic field influences also the course of chemical reaction. The subject has been critically examined by the author in the treatise on magneto-chemistry[183] and from the data then available the conclusion was drawn that a reaction would be accelerated, retarded, or remain unaffected according to whether the sum of the molecular susceptibilities of the products is more than, less than or equal to the sum of the molecular susceptibilities of the initial substances.

The influence of the magnetic field on the phenomenon of adsorption has also been investigated in the author's laboratories.[184] It has been observed that the difference in adsorption inside and outside the fields depends on the field strength applied.[185] Investigations of this type have already provided valuable information regarding the mechanism of adsorption.

9. CATALYSIS AND MAGNETIC PROPERTIES.

It has been observed that a study of the magnetic properties of the catalysts may yield valuable clues to the theory of catalysts. Hedvall, Hedin and Persson,[186] while studying the reaction of $2N_2O \rightarrow 2N_2 + O_2$ using Ni as a catalyst, observed that the rate of decomposition is suddenly increased above the Curie point, although the X-ray investigations by Nunzio [187] do not indicate any difference between the lattice structure of Ni above and below the Curie point. Experiments repeated with samples having different Curie points also indicated an increase in the reaction velocity above the corresponding temperature.

An extension of the work by Hedvall and others [188] has shown that the hydrogenation of carbon monoxide and acetylene by Ni and the formation of CO_2 from CO by Heusler's alloys is much accelerated at the Curie points. The changes involved in the catalysts are also partly structural.

The fact that catalytic activity may have some relation to the magnetic behaviour, was also confirmed in an extended investigation by Taylor and Diamond,[189] who found that the spin isomerization of hydrogen at low temperatures is much more catalyzed by a paramagnetic surface than by a diamagnetic one. Even in cases where the bulk of the material is diamagnetic, the catalytic activity is attributed by them to a paramagnetic surface. This idea, though rather far fetched, would certainly require further investigation.

10. MAGNETO-OPTICAL ANALYSIS.

Allison and Murphy's magneto-optical method [190] of chemical analysis, which depends on the investigation of the time-lag of the Faraday effect behind the magnetic field as a function of the wave-length of the light used, has been the subject of much controversy during recent years. Recently, Slack [191] has reported that, although minima were observed, yet he regarded them as a result of physiological and psychological effects. Furthermore, with Peoples,[192] he reports that attempts to reproduce time-lag measurements and chemical analyses have failed. MacPherson [193] also finds himself in substantial agreement with Slack and others and is unable to confirm sharp minima characteristic of the substances under investigation. More evidence of similar nature comes from Jepperson and Bell.[194] On the other hand Hughes and Goslin [195] seem to have refuted the criticism by demonstrating the reality and reproducibility of the minima photographically. They have used this method for detecting the localization of metals in organs and tissues of animals. Furthermore, Wissink and Woodrow[196] have such confidence in the method that they use it to detect vitamin A, to the presence of which they attribute the characteristic minimum given by many animal and vegetable products.

11. PHOTOMAGNETIC EFFECT.

It is desirable in this survey to include also an account of what may be termed the photomagnetic phenomenon. Light brings about a number of physical, physico-chemical or chemical changes; the magnetic study of these effects should be of considerable value in explaining the nature of the changes involved by light. During the last few years attention has been paid to the magnetic study of photo-phenomena to justify the treatment of the results under a separate head.

Heaps[197] investigated first the magnetic properties of illuminated silver chloride and selenium and showed that no change in the magnetic susceptibility takes place on solarization. Some preliminary experiments on the magnetic behaviour of silver halides have been carried out in the author's laboratories[198] and it has been shown that a change in magnetic susceptibility takes place when these substances are exposed to sunlight for extended periods. Change in the magnetic susceptibility in the case of the iodide can quantitatively be accounted for satisfactorily, if it is supposed that the halide decomposes into the metal and the halogen. The whole subject is at present under investigation.

Another of the vexed problems of photo-chemistry is the phenomenon of phototropy. Phototropic substances are known to undergo a change in colour on exposure to light of a suitable frequency. This change in colour is completely or partially reversible when the exposed substances are kept in the dark for sufficiently long time, heated or recrystallized. Generally this phenomenon is not accompanied by any change in physical properties like melting points, crystal structure, etc. Measurements of the magnetic susceptibilities of phototropic anils, hydrazones, semi-carbazide and anthracene have been carried out before and after exposing them to sunlight in the author's laboratories.[92] The value of the exposed and unexposed samples was found to be the same, except in the case of anthracene[163] where the change is due to photo-polymerization.

From the rate of colour development Padoa[199] suggested the mechanism:

$$A_2 \underset{\text{Dark}}{\overset{\text{Light}}{\rightleftarrows}} 2A$$

for benzaldehyde-phenylhydrazone and salicylidene β-naphthylamine. But it seems more reasonable, as was pointed out by

Senier and Shepheard,[200] to assume that light causes a change in aggregation only and that this change is reversible. If that is so, no change in the magnetic susceptibility may be expected, which is in accord with the experimental facts.

Emberson and Dufford[201] have also looked for a photomagnetic effect in photovoltaic substances and shown that no change in magnetic susceptibility takes place on exposure to light. They suggested that either the magnetic susceptibility is not dependent on the number of free electrons or more probably the photovoltaic effect does not involve the liberation of free electrons.

There are, however, a number of cases where exposure to light has definitely been shown to bring about a change in the magnetic susceptibility, the effect being more or less explicable on theoretical grounds. Bhuyan[202] observed that halogen molecules show an increase in magnetic susceptibility on exposure to light. Although on theoretical grounds the halogens may be expected to be adiabatically dissociated into atoms in the $^2P_{3/2}$ and $^2P_{1/2}$ states, both of which ought to be paramagnetic, the increase in diamagnetic susceptibility observed is probably due to the large number of excited molecules. This is borne out by the observation that the change is completely reversed on taking away the light source.

Bose and Raha[203] have recently extended their earlier work on photomagnetism and found that a positive effect is shown by solutions of vanadium ions in different valency states and by crystals of $NiSO_4 . 7H_2O$. This effect decreases in the order of $Ni^{\cdot\cdot}$, $Cr^{\cdot\cdot\cdot}$ and $Co^{\cdot\cdot}$ and is absent in the solutions of Cr and Ni in hydrochloric acid.

In order to explain their observations Bose and Raha have assumed a sort of loose chemical combination between the molecules of the solvent and the paramagnetic ion, which breaks down on exposure to light. They have concluded that, if the orbital moment is equally quenched in the initial or the final states as in the case of $Cr^{\cdot\cdot\cdot}$ and $Ni^{\cdot\cdot}$ in HCl, no photo-magnetic effect would be observed. The positive effect in the other substances should be attributed to the quenching of the orbital moment. A further study of this effect is bound to be of considerable interest at least from the point of view of the much vexed question of the theory of solutions.

Under the head of photo-magnetic phenomena, the phenomenon of extinction of fluorescence under the action of the magnetic field may also be included, which was observed and studied by Genard[204] in a series of papers. It has been shown that fluorescence excited in the vapours of I_2, S_2, Se_2 and Te_2 by a suitable frequency is considerably and sometimes entirely removed by a magnetic field. On close analysis it has been shown that terms of the same series and quite often the components of the same multiplet are differently affected; the fluorescence of some lines is reduced, and of others is enhanced. In the case of iodine, Genard has concluded that probably an electronic level exists between $^1\Sigma_{g+}$ and $^3\pi_{0\mu}$. This is in agreement with Van Vleck's theory. Zeeman effect alone cannot explain this phenomenon. I hope I have succeeded in showing some of the interesting and fascinating features of this subject.

In concluding this survey, I cannot help hoping that this historic meeting will help us in forging new bonds of personal magnetism which will lead to further advances in Physics and Chemistry and to the cementing of the relations between the East and the West and the old and the new worlds.

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SECTION OF GEOLOGY

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THE STRUCTURE OF THE HIMALAYAS AND OF THE NORTH INDIAN FORELAND

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I. TECTONIC FEATURES OF THE FORELAND.

Geological work carried out during the last few years has thrown much light on the structure of North India, a region of extraordinary tectonic interest, as much on account of the magnitude and intensity of the crustal deformations, involving the upwarp of the Himalayan chain and the formation at its foot of a deep parallel depression, as on the extreme youth of these world-transforming events. The region of North India resolves itself tectonically into two broad belts, the plicated geosyncline of the Himalayas ; and the northern edge of the Indian peninsular massif, that has acted as the *foreland* and in the process sagged under the strain of the folding of the northern orogen. This belt of the passive and inflexible block of Gondwanaland, which bears clear marks of its complicated reactions to the great tectonic and orogenic displacements of Central Asia during late Tertiary and Quaternary times, has received less attention, but is hardly of less interest, from the point of view of structural geology, than the more prominent and striking Himalayan belt.

In this address I propose to deal with the geological structure of (1) the North Indian foreland, and (2) of those parts of the Himalayas that have been investigated in some detail by geologists in India during the last two decades or so, and of their inter-relation in a common tectonic plan.

The chief units of the foreland concerned in this investigation are :—

(1) The Rajputana plateau, prolonged northwards into the 'Punjab wedge' of the Gondwana foreland; it is traversed by the Aravalli range of Algonkian uplift, its tectonic strike being transverse to the main Himalayan trend. (A. M. Heron.)

(2) The Potwar trough, the north-western branch of the Indo-Gangetic depression, whose geosynclinal structure is well exposed, revealing a sequence which epitomises the whole Tertiary history of North India (E. S. Pinfold, D. N. Wadia, R. V. Anderson, G. deP. Cotter.)

(3) The Gangetic trough, a synclinorial depression between Peninsular India and the southern front of the Himalayas, 1,200 miles long and 250 miles broad, of post-Tertiary formation, and filled up by Pleistocene alluviation. (R. D. Oldham, S. G. Burrard, E. A. Glennie.)

(4) The Assam plateau and Assam valley; the plateau is a tongue of the Peninsular mainland; between it and the Himalayan foot is the Brahmaputra valley, a 'ramp valley', filled up by recent alluvium. (C. S. Fox, P. Evans.)

But few parts of the Himalayas have been examined in detail so far for their structural plan. The important work of Medlicott, Middlemiss and Hayden referred mainly to the unravelling of the stratigraphic succession. Of late years the following areas have received considerable attention as regards their geotectonics. Investigation is still proceeding in all these areas and the views here expressed are by no means final but more or less tentative; they may have to be modified in some substantial detail or other by further work :—

(5) The Hazara-Kashmir syntaxis, showing the reaction of the north-western Himalaya against the Punjab wedge. (D. N. Wadia.)

(6) Areas showing over-thrusts and nappe structures in the Simla Himalaya. (G. E. Pilgrim, W. D. West.)

(7) The superposed nappes of Garhwal Himalaya. (J. B. Auden.)

(8) The structure of the Eastern Himalaya, Mount Everest region. (A. M. Heron, L. R. Wager.)

(9) The syntaxial bend of the Assam Himalaya to a reversed direction against the granitic plateau of Assam.

1. *Rajputana and the Aravalli range.*

Detailed field work in Rajputana[5,6] has thrown light on the structure and stratigraphy of the northern sector of the Archæan block of Peninsular India, the Punjab prolongation of which has played a most important part (the 'Punjab wedge') in determining the orogenic trend-lines of north-west India and, according to Mushketov and other Russian geologists, of the Pamir and Ferghana region also. Its most important tectonic feature is the now peneplaned Aravalli range of Archæan and pre-Cambrian rocks, perhaps the oldest true mountain chain in the world, representing a synclinorium of post-Torridonian uplift with a pronounced N.N.E.-S.S.W. strike, in the main transverse to all the later tectonic trends of Northern India. The constituent rocks of the Aravalli synclinorium are Archæan fundamental gneisses, superposed by 3 great systems of Archæan sediments, separated by important unconformities. The crest of this greatly compressed basin-fold dives down underneath the alluvium at Delhi after a N.N.E. course of five hundred miles from Gujarat. It is constituted of the oldest of the post-Archæan systems—the Delhi system—which again exhibits unconformable and fault relations to the next succeeding Vindhyan system, of uncertain Cambrian age. The south-eastern flank of the Aravallis is delimited by a boundary fault against a massive outcrop of the Vindhyans, the edge of which is steeply corrugated and profoundly affected by the last Aravallian uplift. Heron believes the main crust-folding movement of Rajputana to be of Purana, if not later age, and to have infolded the Delhis into the Archæans. The Algonkian (Purana) era in Rajputana was one of igneous and orogenic activity, localized and more or less confined to the Aravalli region, so that outside this orogenic belt the rocks, even though so ancient, are unmetamorphosed.

A north-westerly branch of the Aravallis, striking off from Delhi and extending to the Salt Range, underneath the alluvium, is revealed by geodetic observations; another series of positive gravity anomalies, indicating an upwarp, suggests a northward continuation of the range from Delhi to Saharanpur at the edge of the Simla Himalaya.

The last uplift of the Aravallis must be of post-Vindhyan date (? Caledonian), though it is probable that they may have been rejuvenated at some later periods, before the great Permo-Carboniferous glaciation, during which the Aravallis were a centre of giant glaciers radiating to distant parts of India. No orogenic movement has affected this part of the Indian foreland since the last Aravallian uplift, and subsequent to that the Indian Peninsula has played a passive rôle all through the

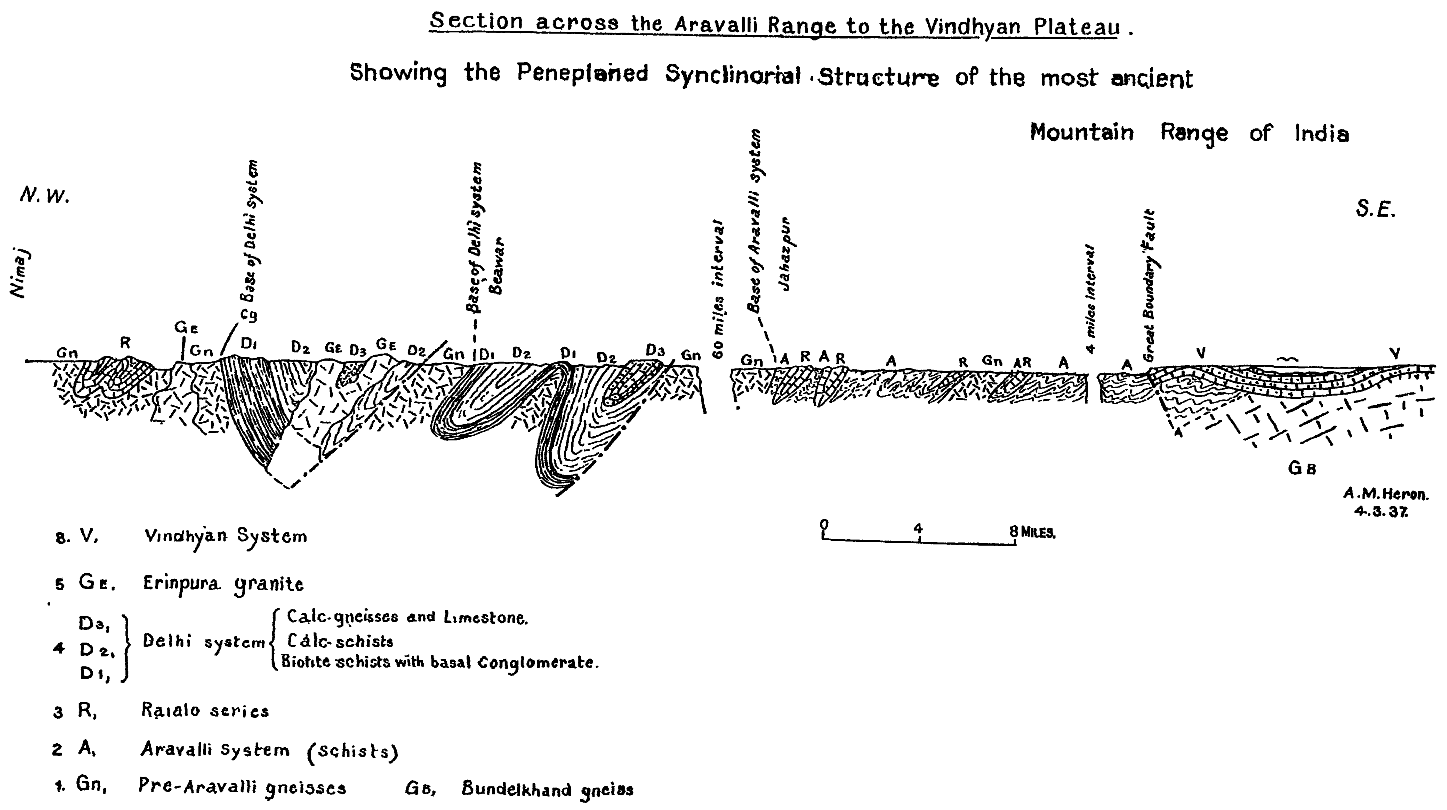
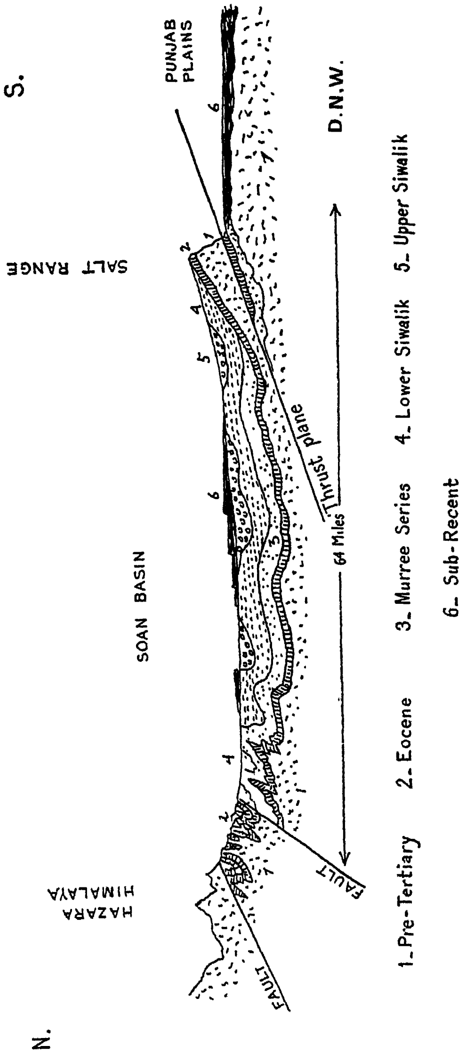

Section across the Aravalli Range to the Vindhyan Plateau.
Showing the Peneplained Synclinorial Structure of the most ancient Mountain Range of India
N.W.
S.E.
Nimaj
Gn
R
Gɛ
Gn
Cg
Base of Delhi system
D1
D2
Gɛ
D3
Gɛ
D2
Gn
Base of Delhi system
Beawar
D1
D2
D1
D2
D3
Gn
60 miles interval
Gn
Base of Aravalli system
Jahazpur
A
R
A
R
A
R
Gn
AR
A
4 miles interval
A
Great Boundary Fault
V
V
GB
A.M.Heron.
4.3.37.
0
4
8 MILES.
8. V, Vindhyan System
5 Gɛ. Erinpura granite
4 D3, D2, D1, Delhi system: Calc-gneisses and Limestone. Calc-schists. Biotite schists with basal Conglomerate.
3 R, Raialo series
2 A, Aravalli System (Schists)
1. Gn, Pre-Aravalli gneisses
GB, Bundelkhand gneiss

Fig. 1.

vista of geological history. The only tectonic movements of this region are of the nature of block-faulting and tensional cracks which, however, have affected the Peninsula on a considerable scale during the Hercynian period and produced, besides a number of long linear fractures, a series of fault-troughs—the Gondwana coal-bearing basins of east India.

2. *The Potwar Geosyncline.*

The Punjab foreland, just north of the Salt Range and the area last described, is a deep structural trough. 25,000 feet of Tertiary sediments, from the Eocene to Pleistocene in a conformable sequence, is folded into this synclinal basin lying between the Salt Range and the skirt of the Hazara Himalaya. This rock sequence epitomises the whole Tertiary geology of North-western India.[8, 9, 11, 13] The syncline is 70 miles broad and 150 miles long, tapering out east of the Jhelum into the Siwalik foot-hill zone. The structural axes in the Potwar region run generally E.N.E.-W.S.W. The floor of the basin is the deeply eroded, peneplaned extension of the Rajputana foreland. Some isolated exposures of its rocks are met with south of the Salt Range in a chain of hillocks near Sargodha, with a north-westerly strike. The Potwar basin is regarded as a north-westerly ramification of the vast Indo-Gangetic trough, into which it merges to the south-east. The simple structure of the main part of the fold is replaced at its northern margin by a series of much plicated isoclines and recumbent folds as the mountain-foot is approached (Kala Chitta and Margala hills). Here the strata are tightly packed and faulted, the dominant structure being isoclinal, all the folds being overthrust from north to south. To the south of this is a broad belt of open folds, with their axial planes dipping north and separated by strike-faults hading in the same direction. The parallel lines of reversed faults (boundary-faults) of the Himalaya become recognisable east of the Jhelum; trans-Jhelum they disappear in anticlines. The southern rim of the Potwar basin is the gentle dip-slope face of the Salt Range with a highly sinuous alignment. In the opposite southern scarp face of these mountains, rising steeply above the flat alluvial plains of the Punjab, are laid bare the Palæozoic and Mesozoic rocks that were deposited on the foreland during prolonged but shallow marine transgressions of the old (pre-Tethyan) Himalayan sea during the Dravidian era and of the Tethys during the Aryan era (the long marine period of the Himalayas from the Uralian to the Eocene). Both these systems of deposits were of the epicontinental type. The southern edge of the Potwar plateau, as revealed in the Salt Range escarpment, is of great interest in the tectonics of Northern India. It reveals tectonic movement of a momentous nature, the whole range having slid forward bodily along a plane of thrust that must have offered such resistance as to impart a highly tortuous base-line to this line of abrupt-faced mountains.[18]



SECTION ACROSS THE POTWAR GEOSYNCLINE

FIG. 2.

Structurally it is a disrupted monocline, its severed upper limb overriding and completely obliterating the southern limb. The Salt Range has lately been studied in detail by E. R. Gee, who postulates a thrust-plane, along which the bottom rocks of the

Potwar basin have moved towards the south, and partly to the east, involving a horizontal thrust of nearly 20 miles.* Its further movement was arrested by the resistance of the Sargodha ridge of the foreland referred to above, which lies buried at no great depth under the alluvium. The great dent in the alignment of the mountain at the Indus marks the site of this obstruction. Tectonic movements in the Salt Range continued into the Pleistocene in sympathy with the later Himalayan orogenic operations.

Between the isoclinally folded Kala Chitta hills and the monoclinally thrust-faulted Salt Range, the Potwar depression lies without notable compression or faulting. To the south-east a portion of the fold is covered up by the Punjab alluvium, another portion merging into the Siwalik belt of Jammu and Simla. The basin structure so pronounced in Potwar gradually flattens and widens into the broad shallow Indo-Gangetic trough.

3. *The Indo-Gangetic Trough.*

The gentle down-warp structure of this region is now generally accepted—a foredeep in front of the crustal buckling of the Himalaya, and produced as a concomitant of that uplift.[4] There is much structural evidence for this belief, against the concept of its being a deep rift-valley or a ramp-valley.[2] It is now regarded as of moderate depth, carrying on its Archæan floor about 15,000 feet of sub-recent river alluvium, overlying a shelving bank of older fluviatile sediments of the Siwalik and Murree epochs (Mio-Pliocene). Recently gravity surveys have been interpreted as indicating a lesser depth for these lighter deposits, aggregating only 6,500 feet,[17] resting on the denser bed-rock. The depth of alluvium is at a maximum between Delhi and the Rajmahal hills and it is shallow in Rajputana and between the Rajmahal hills and Assam. The floor is probably not an even plane, but is corrugated by inequalities. An upwarp of the Archæan rocks in structural prolongation of the Aravalli axis is referred to above. This fact, in conjunction with the observation† of some traces of an older anomalous transverse strike, diagonal to the direction of compression of the Himalaya in the sub-Himalayan belt of Garhwal, suggests that the Palæozoic orogeny of India has not interfered materially with the Himalayan orogeny. It has however played a part in modifying the shape of the Indian trough, producing two festoons on the southern border west and east of the Delhi wedge, the synclinorium being narrowest between Delhi and Hardwar. It was Suess who first regarded the great Indian trough as a ' foredeep ', the Peninsular shield sagging in front of the advancing crust-folds. The boundary between the trough and the Himalayan foot is marked

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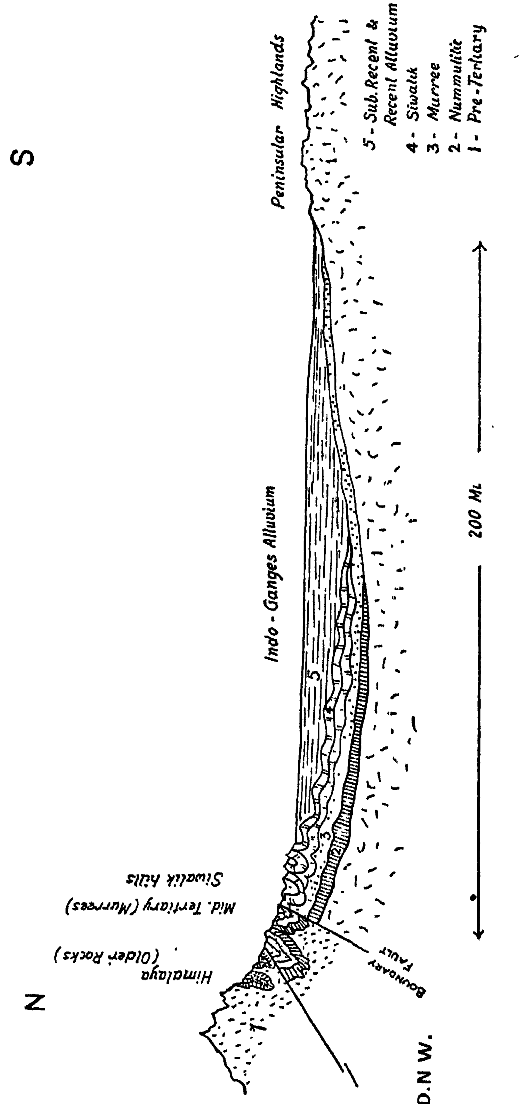
* A memoir on the Salt Range by Mr. E. R. Gee is under preparation.

† C. S. Middlemiss : *Mem. Geol. Surv. Ind.*, Vol. XXIV, p. 183, (1890).



SECTION ACROSS THE INDO-GANGETIC SYNCLINORIUM (Diagrammatic)
(Vertical Scale exaggerated)

FIG. 3.

by lines of parallel reversed faults[1] which, within certain limits can be interpreted as delimiting the boundary of the Outer Himalaya at several successive periods of its uplift, from the

Eocene to the end of the Pliocene. These reversed faults, designated as the 'main boundary faults', can be traced from the Punjab to the Eastern Himalaya, though they cease to be of the nature of limits of deposition of piedmont sediments in the Assam region in the East and in the Poonch hills in the extreme North-West in Kashmir.

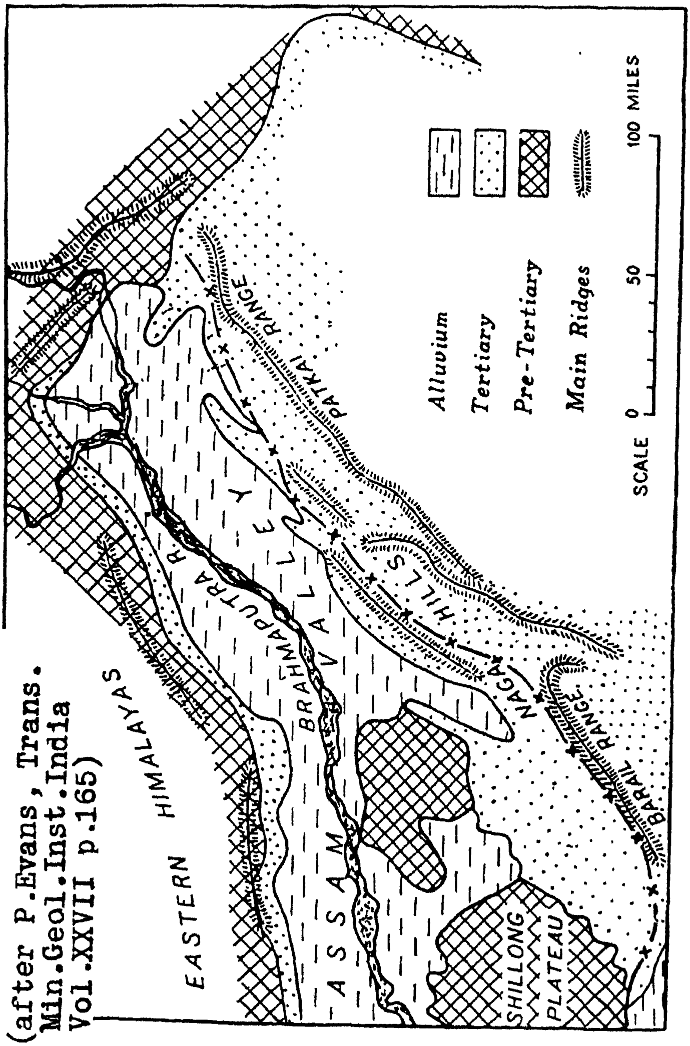
Northward of these fracture-lines are the great thrust-planes along which slices of the mountains have moved to the south, bringing pre-Tertiary rocks of the inner Himalaya in contact with the late Tertiaries of the foot-hill zone. A number of such thrusts have been lately mapped in the west and central Himalaya. The southern limit of the trough shows no structural peculiarities or features of any importance.

The floor and northern border of the great trough is presumably under mechanical strain due to the progressive downwarping, with the greatest subsidence in the sector adjoining the mountain-border. Combined with this is the severe plication along the whole northern rim. It is conceivable that the alluvium conceals a zone of similar folding and faulting further south. The earthquake belt of India runs along the north margin of the plains from the Malay arc to the Iranian arc. The seismic instability of this part of India is well known, it being the site of the epicentres of the great majority of the known Indian earthquakes.

4. *The Assam Plateau and Assam Valley.*

In its composition as well as in geotectonics the Assam ranges and plateau are a part of the gneissic mainland of the Peninsula, being its north-easterly promontory, in strike continuation of the Hazaribagh and Rajmahal hills. Along with the gneiss, some patches of a few of the characteristic Peninsular formations are observed in Assam, e.g. the Dharwars, Lr. Gondwanas (according to C. S. Fox), the Sylhet trap, Upper Cretaceous of Trichinopoly facies and laterite. The intervening Malda gap is due to the erosion of the connecting rocks by the shifting channels of the Ganges and Brahmaputra and to the filling up of the hollow by comparatively shallow alluvium. As in the case of the north-west, or Kashmir cape, this tongue of the foreland has probably played a large part in moulding the axial bend of the Eastern Himalaya around it, as we shall see in the sequel. The post-Archæan rocks of Assam plateau are unfolded and horizontal, as is so generally the case with the Peninsular formations; though on either side of the plateau, to the north and south, at a distance of only a few miles, the Tertiary rocks are plicated, overturned and overthrust, both in the Himalayan foot-hills and in their strike continuation, the Patkai and Naga ranges.

In its geotectonics and in the way in which it has reacted to the crustal movements on its three sides, the Assam promontory of the Gondwana horst is of the highest interest to geologists.



Sketch Map of Upper Assam
(after P.Evans, Trans. Min.Geol.Inst.India Vol.XXVII p.165)

Fig. 4.

According to C. S. Fox and P. Evans, who have carried out detailed field work in the Assam hills and the plateau country, the Assam valley, deeply buried under the Brahmaputra alluvium, is underlaid by the Archæan rocks of Assam, and is a good example of a 'ramp valley' that has by pressure and overfolding been so jammed that its present breadth is only a small fraction of the original. During this process the central granite massif of the Shillong plateau, which acted as the pivot against which the mobile crust moulded itself in a syntaxial bend of the mountains, has not emerged unaffected. According to Fox, the Shillong massif, which presents a long gentle slope towards the Eastern Himalaya, and a steep scarp face to the south, is rent by N-S running cross-faults, which have sliced the plateau into blocks pushing them southwards *en echelon*.

II. STRUCTURE OF THE HIMALAYAS.

We must now turn to consideration of the structure of the Himalayas which rise abruptly from the plains covering the foreland. The edge of the plains, however, does not represent the boundary of the foreland, but as we shall see, a considerable width of the latter is covered under the sub-montane Tertiary deposits of the foot-hills (Sub-Himalaya). The outermost of the thrust-planes discussed in the sequel may be taken to be the real boundary of the Himalayan geosyncline with the Gondwana coast land.

5. *The Hazara-Kashmir Syntaxis.*

The trend-line of the Himalaya is determined by the shape of the Archæan massif of Gondwanaland which is believed to have played a passive rôle against the weaker crustal zone of the Tethys geosyncline pressing southward. For 1,500 miles, from Assam to Kashmir, the Himalayan ranges follow one dominant orogenic strike, at first E.-W., later S.E.-N.W. and then appear to terminate suddenly at the peak of Nanga Parbat (26,620), one of the greatest eminences on the central axis. This abrupt termination was a puzzle; topographic surveys failed to find any line of heights to continue the chain west of the Indus. Geological survey of the country,[10] however, clearly showed a sharp southward bend of the mountain-strike on itself, pursuing at first a south and then a south-west course, through Chilas and North Hazara, instead of pursuing a north-west course through Chitral. All the geological formations and the axis of every individual fold follow this sharp hair-pin bend of the strike as if bent round the pivot of Nanga Parbat. This inflexion, moreover, is not confined to the central ranges only, but it affects some 300 miles depth of the mountains from the Punjab piedmont to the Pamir plateau, which itself shares the same flexure. On the western side of the syntaxis, the Himalayan strike sweeps from the prevalent N.E.-S.W.

to a S.-N. direction in Upper Hazara and continues so to Gilgit (Latitude 36°N.), then it turns W.-E., the Pamir plateau showing a distinct equatorial disposition of the fold-lines. To the south and east of this the main tectonic strike, or 'grain' of the mountains in Astor and Deosai quickly takes a N.W.-S.E. orientation—a direction which gradually changes to a W.-E. trend in Sikkim and Assam. Suess explained the above phenomenon as due to the meeting and conflict of the two opposing orogenic systems of the Himalaya and Hindu Kush, both suffering a deflection and undergoing an acute bend at the line of contact. Stratigraphic and geotectonic facts, as brought to light in detailed field work in this area are, however, decisive against two systems of orography being concerned here, but prove a remarkable identity and continuity of the Himalayan system on the two flanks of the syntaxis. Not only do the stratigraphic systems of Kashmir pass over into Hazara round the re-entrant, but the individual fold-systems and their structural relations with one another are also identical.

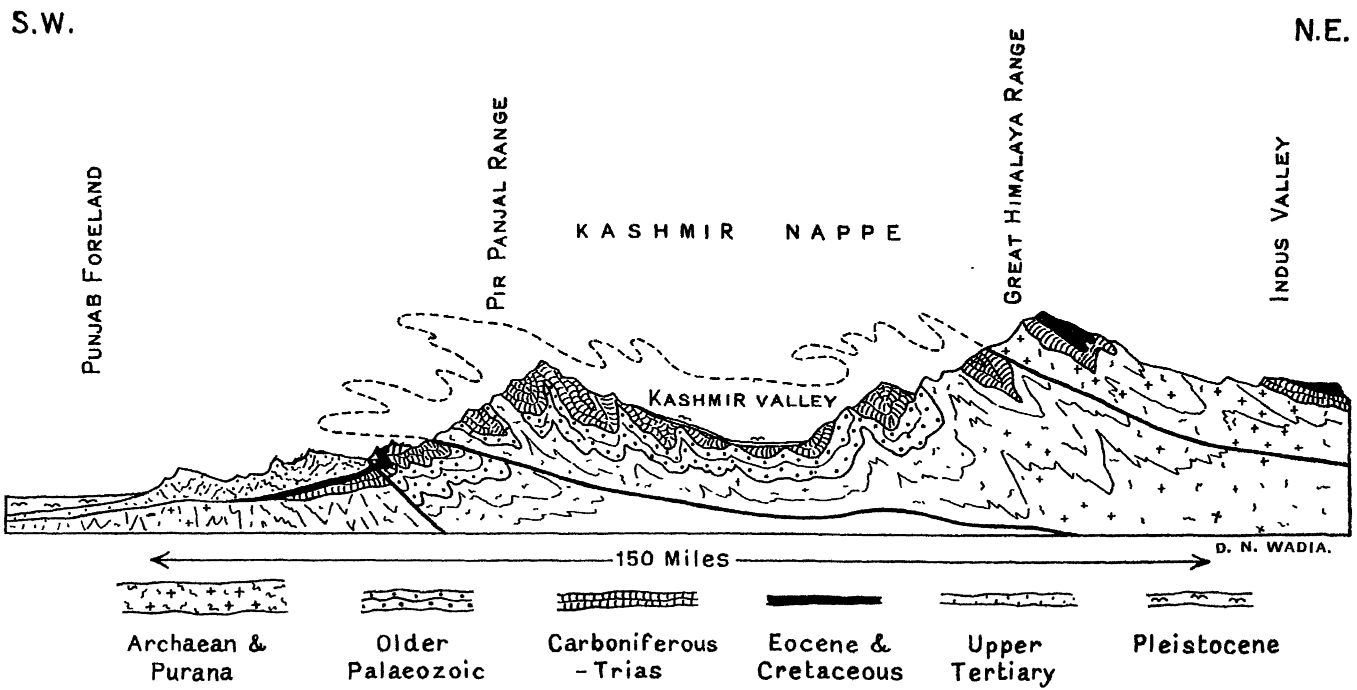
Wadia in 1931 suggested that the acute bend is due to the moulding of the Himalayan orogeny as it emerged from the Tethys round a tongue-like projection of Gondwanaland—the Punjab wedge. On meeting with this obstruction, the northerly earth-pressures resolved into two components, one acting from the north-east, the other from the north-west, against the shoulders of this triangular promontory. Thus it has happened that the Hazara mountains are in their geological structure and composition, a replica of the Kashmir mountains. Westward the axial continuation of the Himalayan geosyncline is observable as far as Campbellpur, beyond which it will be decided by future field work in the Irano-Afghan frontier.

Tectonically the Kashmir Himalaya consist of three structural elements :

(1) The tongue of the *foreland*, its peneplaned surface being buried under a thick cover of Murree (Miocene) sediments.

(2) A belt of *autochthonous*, mainly recumbent, folds consisting of rocks ranging in age from Carboniferous to Eocene, thrust against and over the foreland covered under Murree series (Murree thrust). Southward over-folding and thrusting, with a dominant north-east dip, is the prevalent structural tendency of this region.

(3) The *nappe zone* of inner Himalayan rocks which has travelled far along a horizontal thrust (Panjal thrust) so as to lie fitfully sometimes against a wide belt of the autochthone, at other times almost against the foreland. The Kashmir nappe is composed mostly of pre-Cambrian sediments (Salkhala series) with a superjacent series (Dogra Slate), forming the floor of the Himalayan geosynclinal that has been ridged up and thrust forward in a nearly horizontal sheet-fold. On this ancient basement lie synclinal basins containing a more or less



SECTION ACROSS THE KASHMIR HIMALAYA TO SHOW THE BROAD TECTONIC FEATURES.
(Diagrammatic)

Fig. 5.

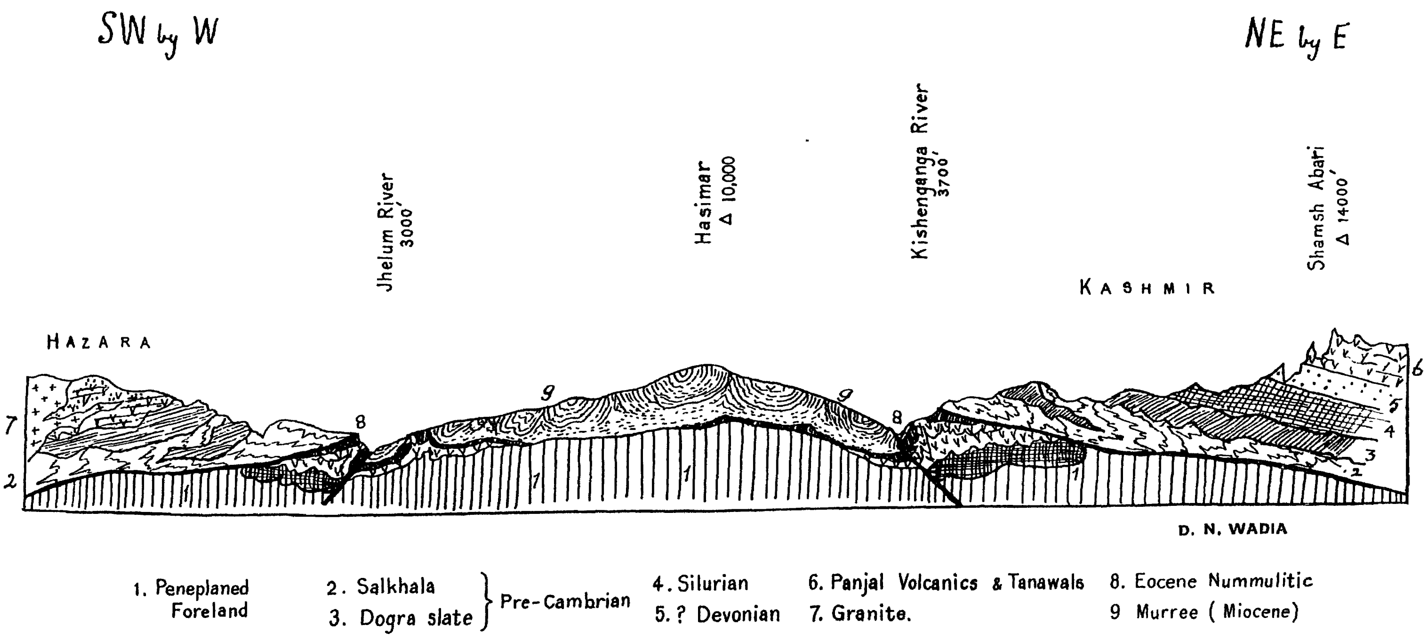
full sequence of fossiliferous Palæozoic and Triassic marine deposits in various parts of Kashmir. The latter are detached outliers of the Tibetan marine zone, which in the eastern Himalaya is confined to the north of the central Himalayan axis.

The most important tectonic feature of this region is the occurrence of two great concurrent thrusts on the southern front of the Himalaya, delimiting the autochthonous belt, which have been traced round the re-entrant from the Hazara border to Dalhousie, a distance of 250 miles. Of these two thrusts, the inner one (Panjal thrust) is the more significant, involving large scale horizontal displacements. The outer, the Murree thrust, shows greater vertical displacement and is steeper in inclination but has an equal persistency over the whole region. In its geological structure, the autochthonous zone between the two thrusts is composed of a series of inverted folds of the Eocene (Nummulitic) rocks, enclosing cores of Upper Carboniferous, Permian (Panjal volcanic series) and Triassic, closely plicated and sheared, but with their roots *in situ*. See Plate V.

In the nappe zone to the north are more thrusts, not easily recognisable in the crystalline complex which builds the Great Himalayan range of the centre. These thrusts, however, are not of wide regional or tectonic significance. As a tectonic unit, the Great Himalayan range is made up of the roots of the Kashmir nappe, the principal geanticline within the main Himalayan geosyncline, consisting of the Archæan and pre-Cambrian sedimentary rocks together with large bodies of intrusive granites and basic masses. Several periods of granitic intrusions have been observed, the latest being post-Cretaceous, or still later, connected with the earlier phases of the Himalayan uplift. A subordinate element of the Great Himalaya range is formed by the southward extensions of the representatives of the Tibetan belt of marine formations belonging to the Palæozoic and Mesozoic.

6. *The Nappes of the Simla Himalaya.*

Detailed mapping and study of the metamorphic gradations in ancient rock-complexes have led G. E. Pilgrim and W. D. West to conclude that the rocks of the Simla-Chakrata area, lying to the north of the Tertiary belt (Outer Himalaya), are not in the normal position as previous observers had believed, but have undergone complex inversions and thrusting.[14, 15] Four overthrusts are noted which have trespassed over the 64 miles broad Upper Tertiary area of Kangra and constricted it to barely 16 miles at Solon. The thrusts represent flat recumbent folds of great amplitude, showing bodily displacement



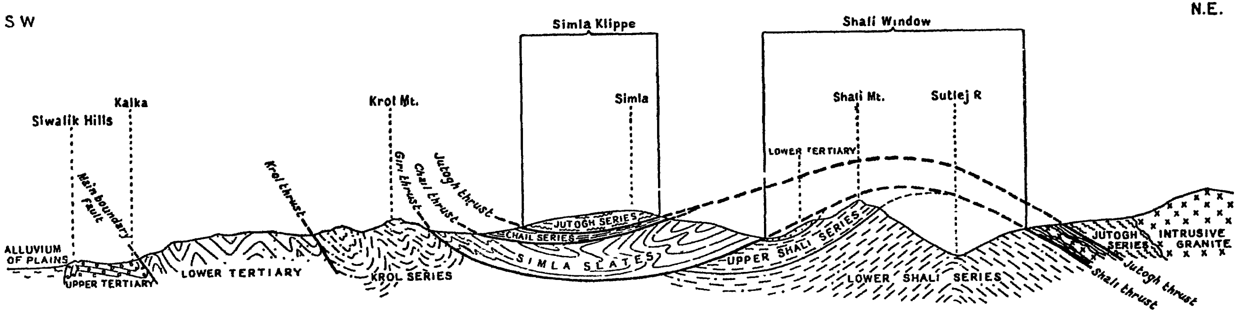
SECTION ACROSS THE HAZARA-KASHMIR SYNTAXIS: RELATION OF THE FORELAND WITH AUTOCHTHONOUS & NAPPE ZONES

FIG. 6.

from the north towards the autochthonous belt of the south-west. The pre-Cambrian (Jutogh and Chail series) is piled up on the Carboniferous and Permian systems (Blaini and Krol series), the entire sequence being totally unfossiliferous. Evidence of the superposition of the highly metamorphosed pre-Cambrian (Jutogh and Chail series), building some of the conspicuous mountain tops of the area (Klippen) over the less altered Lower Palæozoics and Blaini beds (Upper Carboniferous), is obtained by a study of relative metamorphism and the structural relations of thrusts and discordances. The older rocks, now isolated, were once part of a continuous sheet over this area but are now separated from the roots in the north by the deep valley of the Sutlej. To the south of the thrust zone, in the foothills, the older Tertiaries (Nummulitics) are separated from newer Tertiaries of the foot-hills by the series of parallel reversed faults which have been designated as boundary-faults : (1) separating the Upper Tertiary from the Lower Tertiary, and (2) separating the Lower Tertiary from pre-Tertiary rocks. This last 'boundary' fault is really an overthrust corresponding with the Murree thrust of the Kashmir mountains. Medlicott, Oldham and Middlemiss regarded these faults and thrusts not as dislocations but also as limits of deposition, no Upper Tertiary occurring north of the outer fault and no Upper or Lower Tertiary occurring north of the inner fault. Though this conception still holds true to a large extent there are exceptions, here, as in the other parts of the Himalaya, viz. the occurrence of Nummulitic and later Tertiaries to the north of the inner line of faulting.

The nappe zone of the Simla region makes a more striking feature than in Kashmir. It commences some miles north of Solon and follows a meandering E.S.E. course separating the Krol (Permo-Carboniferous) belt by the two great thrusts, Jutogh and Giri, which correspond with the Panjal thrusts of the western Himalaya. The outer limit of the Krol belt is the Krol thrust, corresponding to the Murree thrust of Kashmir. As shown by West and Auden, the Krol thrust itself is steeply folded by later disturbances which have plicated the Krol belt. This Krol belt,[19] which tectonically corresponds with the Panjal range of Kashmir Himalayas, extends along the Outer Himalayas for 180 miles south-east of Solon in a tightly compressed sequence of Permo-Carboniferous strata. Near Solon, Tertiary rocks crop out as windows from under the Krols.

East of Nahan the Krol thrust transgresses southwards and overlaps the main boundary fault. Broadly speaking, the Krol zone of Simla corresponds with the autochthonous fold-belt of Kashmir, but as with the latter area, the autochthone is often greatly narrowed and at places obliterated by the approach of the nappe-front of the gently inclined over-thrust slices from the north. Here and there as at Solon, the Krol zone itself is deformed and thrust forward over the Nummulitics.



SECTION THROUGH THE SIMLA HIMALAYA,
BY W. D. WEST.

FIG. 7.

W. D. West is continuing the field work to the north in this area and is tracing the continuity of the nappes to the root zone in the crystalline area beyond the bend of the Sutlej. He has mapped in the Shali-Sutlej area a 'window' exposing younger rocks by the denudation of the overlying older rocks. The sides of the window are formed of the Chail series showing an *epi* grade of metamorphism. Within the window there occur Upper Palæozoic, Nummulitic and Miocene rocks, dipping centrifugally beneath the Chail cover. The base of the Chails is a plane of mechanical contact and marked discordance, some recumbent folds and thrusts being developed in the Tertiary strata immediately beneath the Shali thrust.

Massive porphyritic granite is intruded on a large scale into the pre-Cambrians. This granite is part of the central crystalline axis of the Himalaya, as in Kashmir and Hazara.

7. *The Superposed Nappes of the Garhwal Himalaya.*

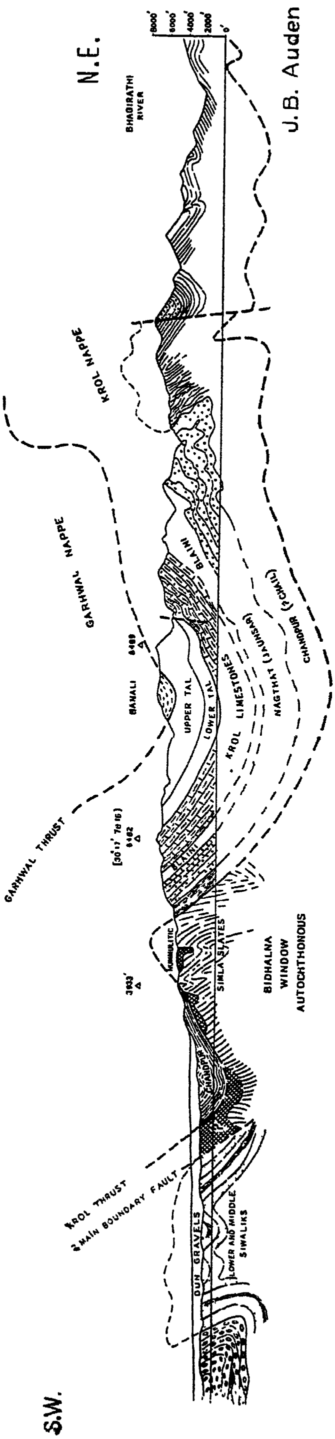
The tectonics of this part of the Himalaya is discussed in a recent paper by J. B. Auden.[20] Two nappes, the Krol and the Garhwal nappe, are superposed one on the other and thrust forward to the obliteration of the autochthone at places. Middlemiss' and Griesbach's previous study of this section of the Himalaya had given, in conformity with the tectonic ideas prevalent then, a simple interpretation to the profile across the Garhwal Himalaya, involving no horizontal displacements.[1]

Proceeding north-east from the Sub-Himalayan Upper Tertiary zone (Siwalik and Dagshai), there are encountered, according to Auden, the following well-defined units :—

(1) The autochthonous fold-belt comprising a substratum of Simla Slates folded in with the Eocene, Dagshai and Siwalik series. Its outer boundary is the reversed fault, 'the main boundary fault' of Middlemiss.

(2) The Krol nappe, comprising a thick succession of rocks in the Krol series (probable Permo-Carboniferous) overthrust upon the Nummulitics and Dagshai of (1). The maximum thickness of the succession in the Krol nappe is of the order of 20,000 feet. This sequence is a normal one and there is no inversion due to recumbent folding.

(3) The Garhwal nappe superposed on the Krol nappe, the relations being such that the Nummulitic, Jurassic and Krol rocks belonging to the underlying Krol nappe, completely surround the older Palæozoic metamorphosed and schistose series of rocks of the superincumbent nappe and dip below them in a centripetal manner. The two major thrusts of the area are seen in Fig 8. The outer, Krol thrust, is continuous with the Giri thrust of the Simla hills and runs south-east beyond Naini Tal. The inner, Garhwal thrust, is not a continuous



The Garhwal Nappes

Fig. 8.

plane but circumscribes cake-like masses of older rocks lying over the Krols in detached ' outliers '.

(4) The Great Himalayan range of crystalline phyllites and schists made up of metamorphosed elements of the Garhwal nappe (which had its root in this part) together with the phyllites, paragneisses and schists, and intrusive granite bodies. It marks roughly the apex of the geanticline within the main geosyncline of the Himalaya.

(5) The Tibetan zone of fossiliferous sediments ranging in age from Cambrian upwards to the Cretaceous is confined to the north of the last zone in this part of the chain, unlike Kashmir, where it occurs considerably to the south of the crystalline axis as well. The high peaks of the snowy central range of the Himalaya, generally composed of granitic rocks define the southern limit of this zone.

8. *Eastern Himalaya—Mount Everest Region.*

The successive Mount Everest expeditions have brought forward data from which it is possible to interpret the tectonics of this region. The stratigraphical work of A. M. Heron,[7] N. E. Odell and later of L. R. Wager[21] enable us to do this. Both the Tertiary (Siwalik-Nummulitic) zone of the foot-hills and the autochthonous belt are greatly narrowed and obliterated in this part, though the tectonic relations indicate the same large-scale inversions and thrusts. The Siwaliks are in mechanical contact with the terrestrial and fluviatile Permian Lower Gondwana beds (autochthonous), which again are overthrust northwards by the pre-Cambrian Daling series of Darjeeling. This thrust bounds the nappe zone of this area, which has here transgressed considerably farther southward over the autochthonous than in the areas we have considered. A broad stretch of undifferentiated crystalline and metamorphic complex, comparable with the Jutoghs and Salkhalas of the western Himalayas, among which the Dalings preponderate, together with intrusive granite and gneiss, builds the mountain-ranges intervening between the thrust-zone and Mount Everest group of high peaks. Detailed field-work in this region may reveal in this basement complex representatives of the Krol and Blaini, embedded in the axial depressions of the horizontally reposing sheet-folds.

Mount Everest and its satellite peaks lie on a culmination of the Great Himalaya range and are largely composed of metamorphosed sediments, originally shales and limestones, now converted to hornfels, finely foliated calc-schists and recrystallized limestones, traversed by muscovite-tourmaline-granite. Mount Everest marks approximately the southern limit of the Tibetan fossiliferous sedimentary zone. Altered and crushed rocks belonging to the latter, rest over the foliated gneissic complex of Everest in a prevalent northerly dip, commencing with metamorphosed Permian series of shales, limestones and quartzites, containing a brachiopod fauna with some deformed *Productus* and *Spirifer*. The actual summit of Mount Everest (29,002) is composed of a limestone coming below this Permian series. From these bottom Permo-Carboniferous to Permian beds there is an ascending series of strata towards the north encompassing the Triassic and Jurassic system, indicating a decreasing degree of mechanical deformation. In the longitudinal synclinal folds into which these are plicated, Cretaceous and Eocene strata are recognized by their fossils. A broad belt of the Mesozoic and Eocene rocks was traversed by Sir H. H. Hayden and Sir Sven Heden during their travels in southern Tibet.

The Eocene is the newest stratigraphic system detected in the Tibetan zone of the Himalaya from Kashmir to Sikkim. Eocene strata are involved in the earliest system of flexures of the inner ranges at both these localities, as well as in Hundes, where they lie to-day at 20,000 ft. altitude.

From the data available we recognize in the chief structure-zones of the Sikkim Himalaya, eastward prolongation of the tectonic zones of Garhwal, Simla and Kashmir, though in greatly varying widths.

9. *The Conjectural Syntaxial Bend of the Assam Himalaya.*

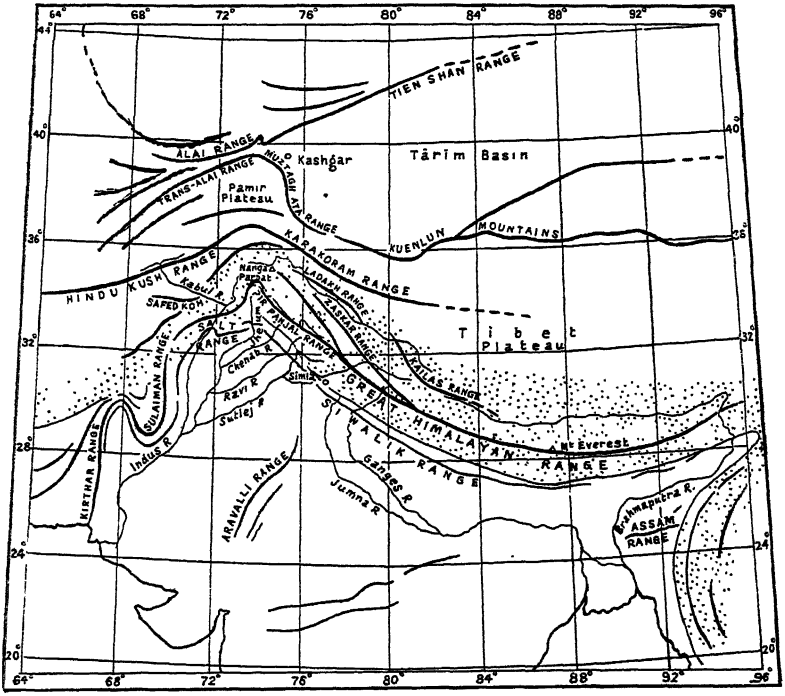
This part of the Himalaya, geologically speaking, is still a *terra incognita* as far as its stratigraphy and rocks are concerned. The tectonics are likewise unknown of the interior parts. Nevertheless the few data that are available from field observations in the Eastern Himalaya, the Abor and Dafla hills, the Sadiya Frontier Tract and the Naga hills permit some tentative views on the strike and alignment of the ranges.[12] The structural strike of the mountains and the disposition of the fold-axes at the above-named localities strongly suggest a deep knee-bend of the Assam Himalaya towards the south, the re-entrant being in this instance deeper and more acute than is the case with the north-western syntaxis. The obstructing block in the present case must be the granite massif of the Assam plateau, connected underground through the Rajmahal hills with the Peninsular horst. (See Fig. 9.)

The south flank of the Assam Himalaya shows a general north or north-westerly dip of the beds, the faults and thrust-planes also hading in the same direction. On the opposite flank of the deep hair-pin bend, enclosing the plateau and the valley of Assam, are the Naga hills, showing south-easterly dips along with a number of strike-faults and thrust-planes, all hading towards the same direction. Percy Evans considers that there is much evident similarity between the disposition of the Tertiary strata of the Assam Himalaya and those of the Naga hills and the age of faulting also, as far as can be ascertained, is the same. The compression of the tongue of foreland enclosed and overthrust by the two flanks of the syntaxis is enormous, as if between the two jaws of a vice.

Palæontological evidence supports the inference that the Himalayan chain bends southwards and does not continue on its eastward alignment into China. The Mesozoic flora of Burma is different from the homotaxial Upper Gondwana flora of India and is more allied to the flora of China—a quite distinct palæo-botanical province from India. This separation of the life-provinces of Gondwanaland and China, lasting from the Upper Carboniferous to the Cretaceous is a fact well established by Halle and Sahni; the cause of this separation can only be attributed to the interposition of the barrier of the Tethys sea. Again, the Cretaceous system of Burma reveals no connection, faunistic or stratigraphic, with contemporary deposits of the closely adjacent Assam province (a part of Gondwanaland), but it shows marked affinities with the Cretaceous of Sind and Baluchistan—a Tethyan province. The Tibetan zone of Himalayan stratigraphy, disposed to the north of the crystalline axis of this mountain chain, extends into Sind on the west side and to Burma on the east.

III. THE OROGRAPHIC TRENDS OF NORTH INDIA AND THEIR RELATION TO THE CENTRAL ASIATIC MOUNTAIN-SYSTEMS.

Recent work in Ferghana (E. Turkestan), and in the Pamir region by the Russian geologists, and in the Himalaya by the Geological Survey of India tends to establish a unity of structural plan and features, disclosing a common cause and origin for all the great mountain systems of Central Asia, both of the Hercynian and of the Alpine age. Fig. 9 is a sketch-diagram showing the alignment of the principal Asian ranges. It is probable, as Argand believes, that powerful crust movements of the Tertiary and post-Tertiary Alpine orogeny superseded, and in a great measure altered, the old Altaid trend-lines of Asia ; the existing alignment of all the ranges, therefore, which meet in the Pamir knot, is largely the work of the late Tertiary diastrophism. The orientation of the Tien Shan-Alai-Kuen Lun system of radiating chains in the north, that of the Hindu Kush-Karakoram arc of the middle, and of the deeply reflexed Himalayan arc in the south, all fuse in the Pamir vertex or knot, a crust segment possessing unique significance as having an equatorial strike orientation in the midst of numerous divergent trend-lines radiating away from it. To the south of the Pamirs is the Punjab wedge, the pivot on which are moulded the Himalayan syntaxis and the Hindu Kush–Karakoram syntaxis. This N–S line of the crust connecting Pamir with Punjab is thus of critical importance in the orography of Asia and will take a key position



The Himalayan Geosyncline and its relation to adjacent mountain-systems (After Burrard & Mushketov).

FIG. 9.

in future work on orogenesis and mechanics of crustal motion in mountain-building.

The festooning of the Himalayan arc, caused by the reaction of the more plastic earth-folds pressing against the Indian horst is of great interest. We have seen the two most prominent of these in the Punjab and Assam wedges causing acute looping of the mountain-arcs. An equally abrupt syntaxis of the mountain-folds which belong to the south-eastern flank of the Suleiman bifurcation of the main Himalayan axis as it joins on with the Iranian arc to the west, is seen near Quetta in Baluchistan. This comparatively minor but most spectacular re-entrant shows a bundling up of a multitude of normal anticlines and synclines of Tertiary, Cretaceous and Jurassic strata into a closely packed sheaf and forced out of straightness by two abrupt curves. These curves, involving a bending of the fold-axes through 120° and 150°, are the result of some crustal peg arresting the free movement of the fold towards the south, under pressures acting from the north or north-west.

From these considerations the view is expressed that the Great Himalaya Range from the gorge of the Brahmaputra in the east to Nanga Parbat on the Indus in the north-west denotes the Himalayan protaxis, the axis of original upwarp of the bottom of the Tethys geosyncline. At both its ends it has undergone sharp southward deflections owing to the termination of the obstruction offered by the north edge of the Gondwana block and its projecting angles and capes.

Stratigraphic and tectonic work in the field have provided no convincing data for fixing with certainty the direction of crustal motion and displacements in the North Indian region, and two contradictory views prevail. The markedly convex trends of the Malayan, Indo-Burma, Himalayan and Iranian ranges, away from the centre of Asia give support to the view which postulates a southward drift or creep of the crust from middle Asia towards Gondwanaland. The irregularities, deviations, and convexities are, on this view, ascribed to the resistances offered by the irregular front of the rigid blocks of Peninsular India, Arabia and perhaps to a less extent north-east corner of Africa. The alternative view does not regard Gondwanaland as a passive resistant block only, but as an active agent in pressing the plastic geosynclinal strata of the Tethys basin northwards. It does not credit a single, united southward movement as competent to produce the convexities of island and mountain arcs (the Pacific arc facing east and the Himalayan facing south-west), but regards underthrusting of the ocean floor and a positive northward drift of the Indian foreland as a more probable source of crustal compression. The latter view has the plausible support of isostasy. For, on a lateral or radial spreading out of Central Asia, there ought to be a defect of matter in the Tibet-Mongol region, which on the contrary, shows a great superficial excess and has the greatest amount of land-mass protruding above the mean sea-level of any region in the world. A northward drift of continental masses, however, remains to be proved. Measurement of the astronomical latitude at Dehra Dun and elsewhere in India has been repeated at different times during the last 100 years ; the results have shown a few irregular changes, but there is no suggestion of any continental drift either to the north or to the south.

On the whole the evidence from structures lends support to the view which postulates tangential pressures from the North. Suess, J. W. Gregory, Bailey Willis, Mushketov and the Russian geologists who have worked in the Pamir-Turkestan field, have all assumed this as the main direction of earth-pressure in the post-Tertiary earth-movements of Central Asia and India.

IV. GRAVITY ANOMALIES IN THE HIMALAYAS.

A volume of data from gravity stations scattered over various parts of the Himalayas has been collected by the Geodetic branch of the Survey of India. Their computation has given results which are at variance with the hypothesis of Isostasy and the views commonly held about mountain compensation. These data reveal a large negative anomaly in the Indo-Gangetic trough area, filled with alluvial deposits, about 18% lighter than average rock and a large positive anomaly, indicating excess of matter in the Outer Himalaya ; while again there is a negative anomaly in the lofty Depsang plateau of Ladak, composed of rocks of normal density. Gravity observations prove that there is a defect of compensation in the outer ranges of the Sub-Himalaya, i.e. the area is one of overload. This defect increases in amount until, according to Oldham, 'at some 50 miles from the edge of the hills it reaches an equivalent to an overload of about 2,000 feet of rock. In the interior of the Himalayas, in the central ranges, observations show that at about 140 miles from the edge of the mountains this overload has disappeared and compensation is in excess.' This fact would indicate that the middle ranges mark a zone of special uplift and that their underload is due to excessive erosion subsequently. These variations in the balance between topography and underground compensation, according to the same authority, lend some corroboration to the theory of support of mountains by flotation but seems to suggest the rather over-reaching conclusion that the growth of the support has been more rapid than that of the range above it ! 'The primary problem then becomes, not as to how the Himalayas are supported at their actual height, but why they are not even loftier ; in other words, the problem is carried one stage further back, from the origin of the range to the origin of its root.'*

These facts are not easily accounted for by Isostasy, but perhaps it is possible to give a satisfactory explanation for the observed discrepancies regarding excesses and defects of mass in the different parts of the mountains on geotectonic grounds, involving a flexuring of the deeper and denser sub-crustal layers in the upheaving of the chain. Col. E. A. Glennie of the Survey of India has suggested a 'crustal warp' hypothesis which seems to offer a possibility of explaining these discrepancies. These crustal warps elevate or depress the denser more basic layers of the sub-crust, which underlie the more acidic rocks of the surface, above or below their equilibrium plane. The theory, however, is still in the stage of examination and trial.[17] Geodetic measurements are charting out regions of excesses or defects of gravity underneath the surface crust in India. From these observations Burrard's 'Hidden Range' has emerged as a fact—a belt of underground excess of gravity traversing the north boundary of the Peninsula from Orissa to Sind, approximately parallel to the trend of the Himalaya. This hidden chain or range of density, which runs quite independently of surface irregularities or geological composition, was first postulated in 1901* by Sir Sidney Burrard from positive and negative gravity anomalies obtained from deflections of the plumb line at a number of stations along and to the north and south of the axis of this feature. The origin of this remarkable feature of underground geology of India has not received any satisfactory theoretical explanation, though Holland's suggestion† that the excess of density is due to a chain of intrusions of dense dunitic rocks to the upper layers of the crust is so far the only plausible explanation offered. The parallelism of the Hidden Range with the Himalayan protaxis cannot be entirely accidental and may have a structural significance, suggesting an upwarp of the *sima* layers, parallel to the downwarp of the Gangetic trough.

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* R. D. Oldham: *Quart. Journ. Geol. Soc.*, London, Vol. LXXII, p. ix, (1916).

V. THE AGE OF THE TECTONICS OF NORTHERN INDIA.

Evidence of the extreme youth of Himalayan orogeny has multiplied of recent years. The tilting and elevation of the Pleistocene lake and river deposits of the Kashmir valley (Karewa series) containing fossil plants and vertebrates, to a height of 5,000–6,000 feet; the dissection of river-terraces containing post-Tertiary mammalia to a depth of over 3,000 feet and the overthrusting of the older Himalayan rocks upon Pleistocene gravel and alluvia of the plains have been noted by the Geological Survey of India and other observers. H. M. Lahiri of the Geological Survey has observed clear thrust-faults at the foot of the Siwalik range of Ambala and Hoshiarpur, Punjab, whereby the Upper Siwalik boulder-conglomerate is pushed over horizontally bedded Indo-Gangetic alluvium, whose age he considers cannot be earlier than sub-Recent. De Terra has made during the last few years valuable observations on Pleistocene orogeny in the North-West Himalaya [22] and correlated the earth-movements there to the later phases of glaciation, which in terms of the standard time scale, would be post-Middle Pleistocene.‡ The initiation of Himalayan mountain-building took place in (1) post-Nummulitic, (Oligocene), time at the earliest, since when the two major phases of upheavals, as revealed by clear stratigraphic evidence, are (2) the post-Miocene, which plicated the broad piedmount zone of Murree sediments, and (3) the post-

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* Sir S. G. Burrard: Survey of India, Prof. Paper, No. 5, Dehra Dun, 1901.

† Sir Thomas Holland: Presidential Address, Geology Section, British Association, 1914.

‡ H. de Terra: Memoir on Pleistocene sequence of India, under publication.

Pliocene, continuing late into the Pleistocene, which has uplifted the Uppermost Siwalik sediments containing *Bos, Elephas,* and some artefacts of prehistoric Man to a steeply inclined or vertical position in the Punjab foot-hills (Rawalpindi and Kangra). The main downwarp of the Plains of Punjab, Bihar and Bengal was concomitant with (2) and (3) phases of Himalayan elevation.

In the Salt Range and in the Assam ranges, two periods of uplift are recognized, (1) post-Eocene or Oligocene, and (2) Pliocene, which continued till late into the Pleistocene. This latter diastrophism was probably a sympathetic event accompanying the final Himalayan phase. The Assam plateau has received also an epeirogenic uplift during late Tertiary.

No Mesozoic or late Palæozoic tectonic movement of orogenic description are detected in the Indian foreland, though minor warps, e.g. minor marine transgressions during the Uralian, Jurassic and Cretaceous, which penetrated the heart of the Peninsula, accompanied by block-dislocations have occurred time and again during the long geological interval. The latest orography of the Peninsula is assigned to the post-Vindhyan —pre-Talchir (Uralian) interval which folded the peneplaned Aravalli synclinorium into a rejuvenated chain, involving in its plication a selvage of the horizontally bedded Vindhyans (? Cambrian) on its east flank.

There was no well-defined Caledonian cycle of earth-deformation in India, while the Hercynian revolutions manifested themselves in initiating the Tethys and in bringing about wide changes in land and water distribution, in tensional faults in the Peninsula, but not in the creation of folded mountains.

The plan of the great edifice of the Himalayas is discernible only in the haziest outline yet. We cannot be so bold as to say that the Himalayas are built on the plan of the Alps, nor even that their architecture is individual. No doubt several tectonic features are common and the Alpine-Himalayan axis of earth-folding originated in one common and continuous impulse. But the proportions are so vastly different, that the very magnitude of the earth-waves raised in the case of the Himalayas gave them a comparatively simpler tectonics, while the smaller convolutions at the other end of the axis may have more severely plicated the shallower surface folds ;—the one may be like an ornately built, delicately chiselled chapel, the other a huge sun-altar of rough-hewn blocks. Perhaps the old pioneers who worked before us recognised this fact and I hope those that follow will not entirely ignore this factor.

Gentlemen, I thank you for your courtesy.

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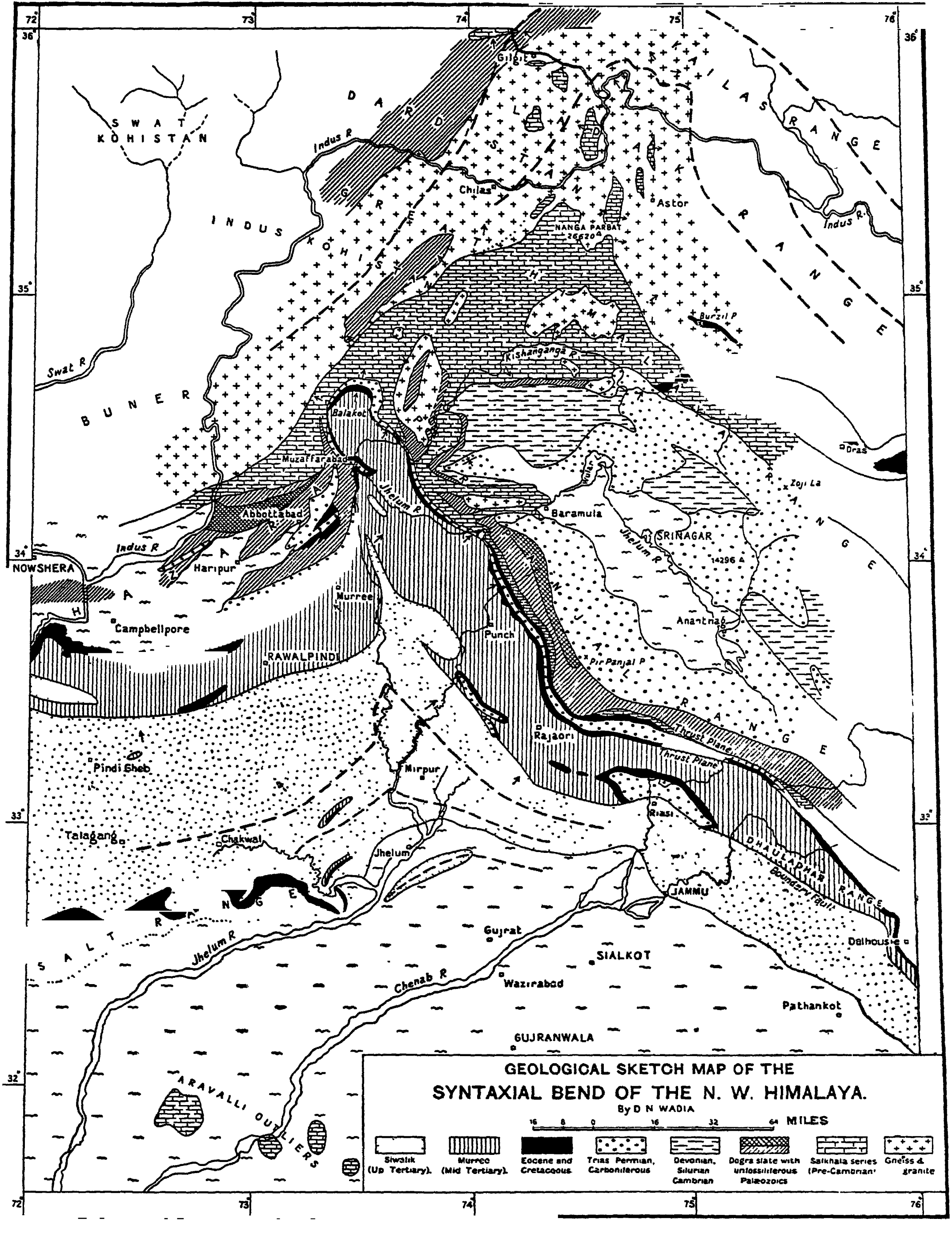

GEOLOGICAL SKETCH MAP OF THE SYNTAXIAL BEND OF THE N. W. HIMALAYA.

By D N WADIA

SECTION OF GEOGRAPHY AND GEODESY

President :—A. M. Heron, D.Sc., F.G.S., F.R.G.S., F.R.S.E., F.N.I., F.R.A.S.B.

Presidential Address

THE PHYSIOGRAPHY OF RAJPUTANA.

As this is the first meeting of a new section, I am fortunate in being spared invidious comparison with preceding presidential addresses, but although there would appear to be a wide choice of subjects upon which to address you to-day, I am limited by my experience.

As I have spent most of my working life in Rajputana I propose to say something about the physical features of that country, especially of the Aravalli range. A condensed account of its geology is given in the *Transactions of the National Institute of Sciences of India*, Vol. I, No. 2, (1935).

First as to its size and shape. It is roughly a rhomb in shape, with east-west and north-south diagonals, the former about 540 miles long, the latter about 510. Its area is 130,462 square miles.

The Aravalli mountains intersect Rajputana from end to end in a line running north-east and south-west, from Delhi to the plains of Gujarat, a distance of 430 miles. They are a true folded mountain range, deeply eroded it is true, but still with several summits exceeding 4,000 feet in height, and are probably the oldest folded mountains on the globe which still remain as a range.

The principal geological interest of Rajputana is in its extraordinarily well developed Precambrian and Archaean succession of six separate systems or series divided by five mappable erosion unconformities :—(1) The Banded Gneissic Complex and the Bundelkhand gneiss, (2) the Aravalli system, (3) the Raialo series, (4) the Delhi system, (5) the Malani series, (6) the Vindhyan system. It is impossible to estimate the immense thickness of sediments involved, but their base must reach very far down indeed into the Archæan.

Three-fifths of Rajputana lie north-west of the Aravallis and two-fifths to the south-east.

The north-western division is sandy, poorly watered and sterile. The eastern part is known in a general way as *Marwar*, a word which is supposed to mean ‘ the region of death ’. This, however, implies an exaggeration, for it is a healthy country with large villages and towns, though widely spaced. Its hardy people emigrate freely to other parts of India as traders and manual workers, and it supplies large numbers of men to the Army. In the west it is more nearly a desert, the *Thar*, a land of sandhills of the *seif* type of North Africa, long narrow ridges running parallel to the south-westerly direction of the prevailing wind; they may be as much as 200 feet in height and 2 miles in length. The *barchan*, or transverse, crescentic, type becomes more common to the north and east, and there are great areas of gently undulating country of whale-backs of sand, waves which appear to be fixed and are thinly dotted with stunted shrubs and tussocks of grass. The central area, containing the Jurassic outcrops of Jaisalmer, Barmer, Bap and Pokaran, has fewer sandhills, and along the north-western foot of the Aravallis is a more fertile tract called *Godwar*, watered by short streams draining the steep north-western slope of the Aravallis. These streams from the Aravallis unite to form the Luni River, which in floods enters the Rann of Kachh. Except for the Luni catchment the rest of western Rajputana is a land of enclosed drainage where the run-off after the rare heavy showers accumulates in innumerable casual depressions amongst the sandhills; some of these have been of sufficient permanence to give rise to deposits of salt and soda. Of these the greatest is the well-known Sambhar Lake, one of the principal sources of salt in India. The Sambhar Lake covers an area of 90 square miles when full, but it is very shallow and generally dwindles to a mere central puddle in the hot weather. It has been found that the average content of sodium chloride in the upper twelve feet of mud is 5·2 per cent., giving a content of salt stored in these upper layers of at least fifty million tons. As the average production is less than a quarter of a million tons per annum, there is no immediate likelihood of exhaustion. The salt is derived from the Rann of Kachh, blown up by the south-west wind in the hot, dry weather and washed into these depressions by the first heavy showers of the monsoon.

The sand of the dunes of Western Rajputana probably has its origin partly in the Rann of Kachh, 'driven by the south-westerly gales which blow across the desert for several months of the year and unimpeded in its advance by streams of running water, it has encroached upon the land until no district is entirely free from it, except those lying immediately at the foot of the Aravalli range, where the numberless water-courses descending from the hills, although they contain running water for only short periods, are able to sweep back the sand blown into them '.[1]

La Touche[2] has noted the presence of fossil foraminifera, derived from the Tertiary rocks of Kachh, to a distance of 500 miles from their origin.

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[1] T. D. La Touche, *Mem. Geol. Surv. Ind.*, 35, Pt. 1, p. 37, (1902).

[2] *Ibid.*, pp. 39-40.

The sand is banked up along the south-western flank of any rocky ridge facing the plain, that is on the windward side, and in the lee of any knoll or small ridge forms a tail extending to the north-east. Between the rock and the sand there is usually a deep narrow ravine, kept clear by the concentrated drainage from the rocks.

Where there are gaps in the Aravalli range, as for instance at the Sambhar Lake and east of Sikar, the dunes extend for miles over the eastern plain, right up to Jaipur City.

Between the foot of the hills and the Luni the country is fertile and water lies near the surface, enabling well-irrigation to be done, but to the westward the cultivation becomes patchy and poorer as the loam shades off into the sandy waste (the *Thar*), while the water-table sinks lower and lower until in Bikaner it is necessary to go down 350 and 400 feet, and even then the water is often brackish.

With a good monsoon, however, which may be reckoned as 10 or 12 inches, even this arid land is covered with light vegetation which supports great herds of cattle, goats and camels.

I quote from Aldous Huxley's 'Jesting Pilate' his description of the Bikaner landscape :—

> 'Once in every ten or twenty yards, some grey-green plant,[1] deep-rooted, and too thorny for even camels to eat, tenaciously and with a kind of desperate vegetable ferocity struggles for life. And at longer intervals, draining the moisture of a rood of land, there rise, here and there, the little stunted trees[2] of the desert. From close at hand the sparseness of their distantly scattered growth is manifest. But seen in depth down the long perspective of receding distance, they seem like the in fact remotely scattered stars of the Milky Way—numerous and densely packed. Close at hand the desert is only rarely flecked by shade ; but the further distances seem hedged with a dense dark growth of trees. The foreground is always desert, but on every horizon there is the semblance of shadowy forests. The train rolls on, and the forests remain for ever on the horizon ; around one is always and only the desert.'

The solid geology of western Rajputana has little effect on the topography, for the rocks are deeply covered by alluvium except where groups of steep, bare hills vary the monotony.

In the south there are gently folded ancient acid volcanic lavas and their associated hypabyssal granites, granophyres and porphyries (the Malani series), lying unconformably on a basement of Archæan rocks (Aravalli schists and pre-Aravalli gneisses), the latter forming hardly any physical feature. Under the insolation of an arid climate, the lava rocks assume strikingly jagged outlines with the smooth desert patina covering their cracked interiors, while the granites are exfoliated and honeycombed into domes and tors, with perched blocks and boulders like cannon-balls and sacks. This is especially the case with the Erinpura granite, post-Delhi but pre-Malani in age, which around Mount Abu and Erinpura gives rise to a tract of bizarre detached hills separated from the main Aravalli range and culminating in Guru Sikar, 5,646 feet. To the north, around Jodhpur, these igneous rocks are overlain by horizontal red sandstones and cherty limestones attributed to the Vindhyan system. The excellent richly tinted building stone which they yield has been utilized to the best advantage in the rose-red cities of Jodhpur and Bikaner and to the vertically scarped, flat-topped hills they form is due to the dramatic appearance of the Jodhpur Fort. Chitor Fort, on the eastern plain of Mewar, is built on a similar cake, but larger, of Vindhyans.

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[1] *Calligonum polygonoides*, 'phog': *Aerua lanata*, 'bhui'.

[2] *Prosopis spicigera*, camel-thorn, 'khejra'.

To the north-west, in Jaisalmer and Bikaner, are extensive slightly elevated areas of Jurassic and Eocene rocks, largely limestones, forming rocky plains scored by the wind-blown sand.

South-eastern Rajputana is morphologically more varied. Essentially it consists of a gneissic plain, typically irregular, of Archæans, which slopes gently eastward from the foot of the Aravalli range to the plains of Hindustan. Its maximum height is about 1,900 feet. This is *Mewar* proper (the stony plains of Mewar, as Kipling calls it), the heart of Rajputana, where the Rajput social order of chivalry attained its purest development and persists with but little change to the present day. Though the soil is thin and stony, it is a fairly well-watered country, with numerous rivers, mere trickles in the dry season, but the tributaries of which are impounded in many large storage reservoirs, facilitated by the ribs of quartz, pegmatite, quartzite and harder rocks which diversify the gneisses. The drainage falls into the Banas, which joins the Chambal and by it finds its way into the Jumna.

In the north of eastern Rajputana this sloping plain falls below the level of the Indo-Gangetic alluvium, but the covering of alluvium does not appear to be particularly thick, and many hills and ridges of quartz-veins, pegmatite and quartzite give clues to the continuation of the gneissic plain below the alluvium.

The great watershed of India, dividing the drainage to the Bay of Bengal from that to the Arabian Sea, passes along the axis of the Aravalli range from the Sambhar Lake southwards as far as Udaipur City. From there, however, it leaves the range and runs south-eastward over the plain.

The tributaries of the Mahi river, which ultimately reach the Arabian Sea, have eroded the plain to the south of the watershed to a much greater extent than have the northward-flowing streams to the Bay of Bengal. This is due to the fact that the length of the rivers from their headwaters here to the sea is about eight to ten times the distance to the Bay of Bengal than it is to the Arabian Sea. The gradient of the latter is accordingly steeper and their erosive power is greater. To the south of the watershed therefore the country is not a plain as to the north, but is a mass of hummocky country, deeply and intricately dissected, known as the *Bagar* and comprising the ' Hilly Tracts ' of Mewar and the States of Banswara and Dungarpur. It is the land *par excellence* of the Bhils, who like to build their scattered huts upon hillocks and burn the scrub jungle for cultivation in the rains. In the valleys the soil is rich in the small patches where it occurs.

In the extreme south-east of Rajputana is the *Pathar* (' stony ') or *Uparmal* (meaning ' higher plateau '). This is the western lobe of the Vindhyan plateau of Central India, and consists of horizontal sandstones and shales faulted against the gneisses of the Mewar plain by the Great Boundary Fault of Rajputana. As usual in the Vindhyans, it is a triple plateau of three concentric scarps formed by the outcrops of three strong sandstones with intervening shales. It is a wide, stony upland, with occasional tracts of deep black soil in the circumferential valleys, and transport is peculiarly difficult on account of the three seldom-broken scarps. Adjoining the Great Boundary Fault to the west is a most interesting area of strangely unaltered Archæans, from which the transition can be traced westward from shales, through slates, phyllites, mica-schists to composite gneisses. The basaltic lavas of the Deccan trap flooded over this land up to the base of the Vindhyan scarp. They are now being denuded, laying bare the old land surface over which they flowed, showing that the old pre-trap surface was much the same in relief as that of the present day. To the south the Deccan trap is continuous with that of Malwa, the fertile plateau of Central India.

On the other side of the Great Boundary Fault from the area of unaltered Archæans, the Vindhyans themselves are thrown into folds and faulted along lines parallel to the Great Boundary Fault for a short distance in to the south-east of it, by compression acting from the north-west. This is a striking departure from the almost universally flat lie of the Vindhyans over the great area in which they are developed, and shows that in Rajputana tectonic movements persisted to a geologically much later date than elsewhere than in the extraordinarily stable Indian peninsula and affected the uppermost Vindhyans.

In his paper ' On the Age of the Aravalli Range ', Sir L. L. Fermor,[1] considering the range as a *horst*, has advanced three possibilities with regard to the age at which this *horst* was produced. His first two alternatives I think unlikely, as they postulate that the Vindhyan rocks of western Rajputana were deposited in continuity with those of eastern Rajputana and Central India. (He indeed himself rejects the first of these two alternatives, from other reasons.) Now all over Central India and eastern Rajputana, a length of 600 miles, the Vindhyans maintain a remarkable uniformity in their sub-divisions, and are from 4,000 to 10,000 feet in thickness. The Vindhyans of western Rajputana, 100 miles away, are only some 300 feet in thickness, and their sub-divisions are unrecognizably different. It would be unlikely for the Vindhyans to remain constant in their intricate sub-divisions over a length of 600 miles, and then in 100 miles to change their succession entirely and to diminish to a tenth of their thickness, and I accordingly believe that the Aravalli range was in existence throughout the period of deposition of the Vindhyans and separated them into two unconnected areas of accumulation. Fermor has pointed out (p. 405) that if this is the case special shore-line conditions should be present in the Vindhyans on both sides of the range. This is so in the case of the Vindhyans on the western side of the range,—gritty and pebbly sandstones, and coarse conglomerates,—but they are absent on the eastern side, the Vindhyans being as fine-grained as usual. This may however be explained by the fact that the Vindhyans here are truncated by the Great Boundary Fault, and may have been deposited far to the west towards the foot of the range, their former extension having been denuded away on the upthrown side of the fault. I shall return to the question of the age of the Aravalli range later, but I may state here that I favour Fermor's third alternative, that the range is pre-Vindhyan in its period of uplift.

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[1] *Rec. Geol. Surv. Ind.*, 62, pp. 403-404, (1930).

In spite of its name, the Aravalli range is composed mainly of rocks of the Delhi system, the massive quartzites of which are responsible for nearly all the prominent ridges which run along the strike. The Delhi system lies unconformably upon the Aravalli system, and is developed in a geosyncline, with the much softer Aravallis exposed upon the flanks. The Aravallis are mostly phyllites, with inconstant quartzites, which, when sufficiently thick and continuous, participate with the Delhi quartzites in the building up of the mountains. Besides quartzites, dominant constituents of the Delhi system are impure limestones, usually altered to calc-gneisses, which, being very hard, form elevated plains or high valleys between the quartzite ridges. Unexpectedly, as they are younger than the Aravallis, the grade of metamorphism and the amount of igneous intrusion in the Delhis are much higher than in the Aravallis. This is explained by the fact that the Delhis in the synclinorium have been more deeply folded into the crust than the Aravallis on the flanks, so that they have reached a lower zone of greater temperature and pressure and more intense igneous intrusion.

In plan, the synclinorium of Delhis appears like a double fan. Where the handles of the two fans meet it is about four miles wide, and it is believed to be here a simple syncline. This comparatively narrow width is maintained for about forty miles along its length, and then at either end it spreads out into the two fans, by the appearance of additional folds, by a thickening of some of the formations and by deeper folding bringing in higher beds in the central core.

In the northern fan erosion has been more effective than in the southern, and little more than the quartzite ridges of the Delhis remain, the softer upper rocks, phyllites and limestones, being worn away in the synclinal valleys and largely concealed by alluvium. The folds are isoclines, the axial planes of which dip towards the north-west, and they pitch to the north-east. That is to say, the older rocks are exposed to the south-west, the base of the Delhi system being exposed in bays or festoons upon them, and if one passes along the fold-axes towards the north-east one finds successively younger beds coming in.

All along the Aravalli range, if one considers a cross-section of the range at right angles to the strike at any point, one finds that the degree of metamorphism and amount of igneous intrusion increases in a direction from south-east to north-west. So for example in this northern fan of the range, the same generalization holds with regard to the folding. In the furthest east, in the Biana hills,[1] the beds dip at 10°–20° and are little altered. Igneous intrusives are absent. As one passes north-westward the folding steepens to the Jura type, pegmatites and quartz-veins appear, and shales become phyllites. Further north-west still the isoclinal folding I have mentioned sets in and large bosses of intrusive granite appear, with abundant earlier and smaller bodies of basic rock, and a great development of pegmatite in the softer rocks.

The basement beds of the Delhis in this portion of the synclinorium show great thicknesses of conglomerates, occasional tuffs and effusive lavas, and unconformities and overlaps, betokening shore-line conditions and the oscillations of level which take place on a land margin. This land area, corresponding with much of the present Jaipur State, was apparently occupied by the oldest gneisses, and the Delhis were deposited in a sinking tract to its north and east.

The synclinorium narrows from the Sambhar Lake southwards and is seen to consist of two synclines of the Delhis, with a long narrow tongue of pre-Aravalli gneiss between them. An important thrust-fault runs along the north-west of this medial tongue and ultimately brings the two synclines together. This thrust-fault reaches the plain in the neighbourhood of Desuri, but for most of its length it runs within the range and cannot be identified with Sir L. L. Fermor's postulated 'western boundary fault somewhere to the west of the western foot of the Aravalli range'.[1]

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[1] *Rec. Geol. Surv. Ind.*, 48, pt. 4, pp. 187–193, (1917).

The north-western of the two synclines becomes obliterated to the south-west by the intrusion on a large scale of basic and granitic igneous rocks. The south-eastern, as I have mentioned, is more or less a simple syncline for some 40 miles along its length, but south of Desuri it fans out into numerous folds, forming narrow valleys and long bold ridges developed by the quartzites and mica-schists of the lower portion of the Delhis, while much dissected plateaus mark the less complicated structure of the limestones, calc-schists and calc-gneisses of the upper Delhis.

Where the folds disappear under the alluvium of Gujarat the rocks are comparatively unaltered on the eastern flank of the synclinorium, and there is no igneous intrusion. The western flank, however, is saturated with granite and pegmatite intrusions and in the south they invade the central core and replace large areas of the sedimentaries.

I have mentioned the strong quartzites of the Delhis, which give rise to prominent ridges by the mapping of which the structure is apparent. When one looks at these grouped ridges from some distance away, one is at once struck by their wall-like appearance and their long level tops. This was remarked on by the first observer in the region, J. B. Fraser, in 1824. This has nothing to do with stratification, unlike the case of the Vindhyan plateaus built up of horizontal sandstones, for in the Delhis the rocks are usually steeply dipping, or even vertical. When the range is considered as a whole, it is clear that these level summits form remnants of a greatly dissected peneplane. Hardly a single peak projects above their general local level, with the exception of the mountain mass of Abu, which however lies apart to the west of the main range, and is entirely composed of granite. It may still have been mountains rising above the peneplane when the latter had been denuded to a level, or it may be a special elevation.

In the heart of the range, north-west of Udaipur City, the level of the peneplane reaches 4,000 feet above sea-level, falling gradually to the north-east and the south-west along the axis of the range.

In the Alwar hills it lies at a height of 1,800 to 2,200 feet, and to the north, in its last extension in the hills south of Delhi, it falls to 1,000 feet above sea-level, only two or three hundred feet above the level of the plains.

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[1] *Op. cit.*, 62, p. 402, (1930).

It was thought by Middlemiss [1] and myself [2] to be traceable down to the floor on which were deposited the Ahmednagar sandstones, a local plant-bearing formation of Wealden, Lower Cretaceous, age, at the southern end of the Aravalli range. Marine transgressions laid down also the Jurassic and Eocene beds of Kachh and western Rajputana, and the Cretaceous Bagh beds. It has since been found, however, that the peneplane does not slope gradually down to the base of the Ahmednagar sandstone, but ends about 400 feet above it. The peneplane is thus older than the Lower Cretaceous by a space of time during which 400 feet of quartzites were eroded, but would still probably be Mesozoic.

Sir L. L. Fermor, in his paper [3] which I have quoted above, argues that the Aravalli tract should be regarded as a horst, bounded on the east by a fault of some 5,000 feet maximum uplift, *i.e.* the Great Boundary Fault of Rajputana, and on the west by a hypothetical or suggested fault.of the same order of magnitude, though not necessarily of the same amount; he admits the absence of any observations proving the existence of such a fault. This has not been detected, and if it occurs close in to the western foot of the range I do not think it could have been missed, if existent, for since he wrote the paper Dr. Coulson, Dr. Ghosh and I have been over the country in which we might have expected to find it. If, on the other hand, it runs far to the west of the foot of the range, for instance to the west of the Abu mass, it could easily be missed in the wide stretches of alluvium. Alternatively, if a western boundary fault cannot be found, he suggests a tilt.

Earlier in this address I have pointed out the probability that the eastern and western Vindhyans were deposited in separate basins, and that the Aravalli range was still the barrier separating them.

As I have just said, I prefer Fermor's third alternative—that the Aravalli range was upfolded in pre-Vindhyan times, and the Vindhyans were derived in part from its denudation. At the close of the Vindhyan period this range was still in existence, separating the two Vindhyan areas. We do not know whether it continued to rise *pari passu* with the deposition of the Vindhyans. From the existence of the Great Boundary Fault and the folding of the Vindhyans, up to the youngest, along it, we are certain that at some time after the deposition of the latest Vindhyans we know of, compressive stresses came into action again. How long after this I shall try to indicate, but we do not require to assume the pre-Talchir rejuvenation which Fermor suggests.

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[1] *Mem. Geol. Surv. Ind.*, 44, pt. 1, p. 90.

[2] *Op. cit.*, 45, pt. 1, p. 8.

[3] *Rec. Geol. Surv. Ind.*, 62, pt. 4, pp. 402-403, (1930).

Two dramatic cases of superimposed drainage are given by the two principal rivers of Rajputana. Between Rampura and Kotah the Chambal cuts straight through the three Vindhyan scarps, without regard to structure, though its tributaries occupy strike valleys excavated in shales at the foot of the sandstone scarps. The Banas at Rajmahal, wandering through the plains of Jaipur, breaches a great isolated flat-topped ridge of Delhi quartzites in a picturesque gorge, swinging through a right angle before entering it, instead of proceeding on an uninterrupted course round the end of the ridge. The case of the Chambal might be one of ‘ cut-back and capture ’, but one cannot believe that of the Banas, where the selection of the only ridge in the neighbourhood for its attack is outside the range of probability. One can only infer that in the case of the Banas its course across the ridge was in existence before the Mesozoic peneplane was warped, and cut down vertically as the plane arched. In the case of the Chambal it is possible that its direction was established when Deccan trap covered the area up to the outer scarp, and that the Deccan trap surface determined the direction of flow.

The range appears to have been peneplaned during the Mesozoic, at some time not very much earlier than the Cretaceous. This may well have been the first peneplanation since the range arose in pre-Vindhyan times. The peneplane has since been warped in such a way that its central portion in Udaipur is now some 4,000 feet above sea-level, its north-eastern end near Delhi about 1,000 feet and its south-western end in Gujarat about 1,000 feet above sea-level. Now land cannot be worn completely down to sea-level, for its base-level of erosion must always be determined by the final gradient of the streams eroding it, below which they cease to operate. This we may try to estimate, for the Aravalli range, by considering the present level of the plains, which will give us values close enough for our purpose, as the plains of India have very nearly reached the stage at which their rivers can no longer eat them away. We may take this as about 650 feet at Delhi, 500 to 700 feet in western Rajputana, west of the centre of the range, and 700 feet on the Gujarat margin.

On these assumptions the uplift of the range, since peneplanation, has been some 300 to 400 feet at its ends, and 3,500 feet as a maximum in the centre.

The maximum figure given for the displacement of the Great Boundary Fault, 5,000 feet, is therefore not far different from the maximum warping of the Mesozoic peneplane, and the throw of the fault is believed to decrease from about the centre of its arc where the maximum occurs, towards either end. Near Chitor, in fact, the upthrow changes from the western side to the eastern.

The suggestion is now made that the elevation of the peneplane, or the Mesozoic rejuvenation of the Aravalli range, and the production of the Great Boundary Fault, may be closely connected and contemporaneous. It will be seen that the western lobe of the eastern Vindhyans would act as a ram or wedge, which by thrusting under the Aravalli tract from pressure acting from the north-west might tilt it along its eastern side, lifting it from a hinge-line to the west, thus rendering it no longer necessary to suppose a fault along the western side of the range.

It seems somewhat startling to ascribe a late Mesozoic age to a structure which has hitherto been tacitly supposed to be very ancient, but in the closing paragraphs of the paper which I have quoted, Fermor sounds a note of caution in ascribing to present features of India a too great antiquity. We know, of course, of the great faults of post-Gondwana time which have let down the coalfields into the gneisses and preserved them, and Dr. Fox[1] has found that the throw of the post-Deccan-trap fault of the Gawilgarh hills, north of Ellichpur, is at least 1,800 feet and might be as much as 4,000 feet.

In the case of the Great Boundary Fault of Rajputana, we can place an upper limit to its age, for it runs below the Deccan trap, which lies undisturbed upon it, and it is thus pre-Tertiary.

The straight steep western coast of India has been supposed to be a cut-back fault-scarp, the hypothetical fault running at some unknown distance out at sea. This fault, if it does occur, must be later in age than the Deccan traps, as they constitute the supposed fault-scarp. Lt.-Col. R. B. Seymour Sewell[2] has recently made the interesting suggestion that the great submarine ridge which extends due south from the west coast of India, and on which are situated the Laccadive, Maldive and Chagos archipelagoes of coral-atolls, is a continuation of the Aravalli range. It is possible that this submarine ridge was submerged by its foundering on the downthrow side of the hypothetical West Coast fault after the pouring out of the Deccan traps, and therefore at a later date than the rejuvenation of the Aravalli range by compression and faulting acting before the time of the Deccan trap.

On these assumptions the Aravalli range was peneplaned in the Mesozoic, re-elevated before the beginning of the Tertiary, and the southern prolongation of it, now under the sea, was let down in the Tertiary, after the accumulation of the Deccan traps.

A second possible peneplane, but one about the reality of which I am not nearly so certain, is represented by an erosion surface on the softer rocks, phyllites, schists, gneisses and some of the granite areas. This is best developed on the plains to the east of the Aravalli range, but forms the floor of the broad strike-valleys within the range. Rising above it we have not only the great even-topped ridges of Delhi quartzite, topped by the Mesozoic peneplane, but many residual resistant masses, due to the harder epidiorites and granites, quartz-reefs, minor quartzites, limestones and such less easily eroded rocks. For considerable areas it may be covered with superficial deposits of no great depth, through which the streams cut down to rock. Its margins dip under the alluvium of the Indo-Gangetic plain and Gujarat. It is not so much a continuous plane as a series of planes, at slightly differing levels, falling in steps from the centre of the range to the plains bounding it. The heights of these planes are determined partly by the character of the rocks of which they are composed, and partly by the extent to which erosion has been retarded in certain of the higher valleys by rock-barriers impeding the drainage and hindering the cutting-down action of the streams. As an instance of the effect of the nature of the rocks on the levels of adjacent parts of this plane, I may mention that the upper portion of the Delhis, above the strong Alwar quartzites, consists of three types of rock, exposed in the heart of the range (1) limestones and calc-gneisses with normally few intrusives, (2) flaggy calc-schists with numerous small pegmatites, (3) mica-schists riddled with small and large pegmatites. These three divisions are intrinsically different in their lithological character and, in consequence, in their behaviour under denudation, the calc-gneisses and limestones being the most resistant and the mica-schists least, and in addition they are weakened by the pegmatite intrusions in them. As a result a set of three stepped planes is developed from them, that on the calc-gneisses and limestones being the highest, forming long narrow plateaus along the range, flanked by shelves cut out in the calc-schists, and bounded by more depressed belts along the mica-schists. Roughly speaking, there may be differences of some fifty or even a hundred feet between the three planes taken at any cross-section, and the modern stream system has deeply incised them all.

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[1] *Rec. Geol. Surv. Ind.*, 62, pt. 4, p. 409, (1930).

[2] *Mem. A.S.B.*, Vol. IX, No. 7, pp. 439–442, (1935).

If this peneplanation is really a unit, and not a fortuitous effect resulting from the even erosion of foliated rocks which, looked at broadly, are mostly fairly homogeneous, it may perhaps represent the Tertiary peneplane which has been detected in other parts of India, *e.g.* by Dr. J. A. Dunn in Chota Nagpur.

There is yet a third peneplane, of Pleistocene or Sub-recent age, that of the *bhangar*, or older alluvium of the Indo-Gangetic plains. At Agra on the Jumna the level of this is about 170 feet and the tributaries of the Jumna cut into it to a depth of 90 feet. The older alluvium is a yellow clay, somewhat cemented by carbonate of lime, which forms the familiar concretions known as *kankar*, so extensively used all over the plains of India as road metal and a source of lime. It approximates to loess in character and is the combined product of river flood and wind action. *Kankar* is a Hindustani word meaning ‘ gravel ’.

As it has a certain amount of consistency under rainfall, when eroded it stands up with steep slopes, and gives rise to the narrow belt of 'bad-lands' which fringes most of the rivers. This is not well seen at Agra, but where the road and railway cross the Chambal river south of Dholpur, on the way to Gwalior, the fretted sculpturing is impressive, in a maze of tortuous ravines, the topography of which is well displayed on the one-inch map.

To the south, in the centre of Rajputana, where it meets the peneplane or 'pseudo-peneplane' of Tertiary age which I have just mentioned, the alluvial peneplane rises to about 1,400 feet, and on the western side of the Aravalli range it lies at about 1,000 feet. Near the mountains the level of the alluvium rises somewhat rapidly, but this is due to the heaping-up of wind-blown sand in a ramp. The sand-hills of western Rajputana are accumulated on this peneplane, out on the desert away from the hills.

I have put these notes together to attract attention to various points in the tectonics of Rajputana. The structure was evolved first by the intense folding of the ancient Aravalli range, and, more recently, geologically speaking, by faulting and more gentle warping movements which may have initiated the fissure-eruptions of the Deccan traps. As my years in India are numbered, I leave it to my geographical and geological colleagues to test my suggestions in the larger field of the structure of the Indian peninsula as a whole, and, speaking both in a figurative and a Wegenerian sense, its repercussions on the tectonics of the Himalaya.

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SECTION OF BOTANY

President :—B. SAHNI, M.A., D.Sc., Sc.D., F.R.S.

Presidential Address

RECENT ADVANCES IN INDIAN PALÆOBOTANY.*

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* As this address was intended to be a helpful summary of recent work I have thought it useful to add what I believe is a complete, or nearly complete, bibliography of the works published since the subject was last reviewed in 1921 (see Sahni 1922). The text as here printed is also much fuller than the address actually read.

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LADIES AND GENTLEMEN,

We are celebrating the Silver Jubilee of our Indian Science Congress in the presence of a galaxy of scientists from abroad. I am deeply sensible of the honour that has been done to me by the invitation to preside over the Section of Botany at this historic session.

Festive occasions often have a sad touch about them, and today we meet under the shadow of the death of two great men : Lord Rutherford, who was originally chosen to preside over us and Sir Jagadis Chandra Bose, the first amongst us to light the torch of science in this country. Let us honour their memory by standing in silence for a moment.

INTRODUCTION.

About 12 years ago, when I had the honour of presiding over the Geology section, I said that fossil plants represent the debt that botany owes to geology.[80] And I then made an attempt to show how far we botanists can repay that debt by the study of fossil plants as an aid to geology. This morning I propose to take up the same theme. It was not till after the Great War that the study of fossil plants was revived in India, through a branch of the Cambridge school inspired by that doyen of palæobotanists, Professor Sir Albert Seward.[134] This revival we may date from our Calcutta meeting of 1921 [75] and it is gratifying to feel that in the meantime the field of palæobotany has become a happy meeting ground for botanists and geologists in this country.

I think that for the purpose of my address this is a particularly auspicious occasion. For we are meeting again in Calcutta, where this Congress was born, and Calcutta is the home of our Geological Survey, under whose auspices were laid the foundations of palæobotany in India. With its large resources the Geological Survey has continued to add to the scientific treasures of the Indian Museum, and to guard with jealous care the many irreplaceable type-specimens placed in its charge, which are so indispensable to future generations of students.

The work of the last seventeen years on Indian fossil plants has marked an advance both from the botanical and the geological point of view.

Botanical aspect

To the botanist, recent explorations in the field, and even a revision of the old collections in museums, both in India and abroad, have revealed new forms of plant life, some of them of great interest, or have extended his knowledge of species hitherto obscure. While the strata hold endless promise of future discoveries, intensive work in the laboratory is helping towards a richer appreciation of what we already possessed. Knowing by experience that trivial points in the structure of plant-remains often yield valuable clues to identity, the palæobotanist has cultivated an eye for detail such as a Sherlock Holmes might envy. A minute comparison of detached fragments has thus enabled him to correlate them as parts of one and the same plant, and even to attempt a reconstruction of the plant as it probably appeared in life. The investigation of fossil cuticles and spores, often retrieved from specimens once abandoned as useless, has revised his ideas concerning the affinities of plants long known under misleading names. In clays and shales previously thought to be sterile the microscope has revealed a wealth of life in the form of pollen grains and other resistant parts of plants, which are often highly characteristic of genera and species. Lastly, the comprehensive revision of a whole group of plants has thrown light upon its distribution in Time and Space, its range in structure, its affinities and evolutionary tendencies, its reactions to a changing geological background.

I think I have said enough at least to indicate the scope of the recent work on Indian fossil plants so far as it concerns the student of botany. We may now refer briefly to the way in which this work has impinged upon the domain of geology.

Geological aspect

To the geologist this work has not only been helpful in tackling problems of stratigraphical correlation, but has also thrown light upon questions of palæogeography, past climates and even earth movements, both of the vertical and of the horizontal type. At the same time it has had its importance in connexion with economic enquiries.

Sometimes, as we shall see, the palæobotanist has arrived at conclusions regarding the ages of strata which were at variance with those long held by geologists, but which have ultimately been supported by a variety of independent data. In other cases the palæobotanist, working solely on his own evidence, has visualized certain features in the geography of the past, or has explained the geographical relations of extinct floras by postulating certain tectonic movements, and his views have found welcome confirmation in the light of geological facts.

To attempt on this occasion anything like a detailed review of the recent work is out of the question. All we can hope to do in the brief time at our disposal is to follow up a few selected lines of advance. Incidentally we shall see that the botanical and the geological points of view are sometimes so intricately mixed up that a separate treatment is neither easy nor profitable.

EARLY PALÆOZOIC FLORAS.

Possible discovery of Psilophytales in India.

From a cursory review of our fossil floras [75], which I undertook in 1921, prior to a detailed study, it appeared that an important gap in our knowledge lay in the earliest plant bearing strata. This gap still remains, for we have no evidence from this country of that primitive race of land plants, the Psilophytales, which had an almost worldwide distribution during the Devonian period. But the position seems to have become rather more hopeful of late. Recent geological work in Kashmir and Hazara has shown that land conditions prevailed in this area during the Siluro-Devonian period, when the Psilophytales flourished in many parts of the world. We may therefore look forward to the discovery of this ancient flora in any brackish or fresh water deposits of this age that may be exposed in this region. Such a hope is justified by the recent discovery of this group in the Silurian rocks of Australia on the one side and of N.W. Europe on the other. Only a couple of years ago Prof. Halle described some Psilophytales from the Devonian of China. In the Ordovician and Silurian shales of Spiti (in the N.W. Himalayas) traces of plants were found a little over thirty years ago, but although several of them have the repeatedly forked habit of the Psilophytales, no sign of vascular tissues or of the large terminal sporangia with cutinized spores characteristic of this group has so far been discovered. A critical examination of the plant-bearing shales may yet reveal the existence of this ubiquitous group of plants in the Himalayan region.

In their uniform simplicity these ancient vascular plants almost touch the Thallophyte level, and we all know that they were at first actually taken for algæ. Their almost cosmopolitan distribution in such early rocks may seem to lend support to the idea that they arose simultaneously from aquatic ancestors in many far scattered parts of the world ; but I think that such a view probably underrates the enormous period of time which these plants had at their disposal for dispersal through space. Although generally referred to a single phylum they are more probably a plexus of groups containing the roots of several lines of evolution. Evidently the origin of those two mysterious substances, lignin and cutin, which still distinguish vascular plants from their probable ancestors, the Algæ, is to be sought further back in the geological record than we had ever imagined.

THE PO SERIES OF SPITI.

Basal part, Lower Carboniferous: evidence of plant-fossils.

The value of fossil plants as an index of geological age has been strikingly demonstrated in a recent revision of a small flora from Spiti.[20] The plants occur only in the basal part of the Po Series of strata, known as the Thabo stage. They include *Rhacopteris* and other plants characteristic of a period when a uniform type of vegetation appears to have flourished in the northern and southern hemispheres. Professor Zeiller of Paris had long ago compared this flora with Lower Carboniferous species from Europe on the one side and Australia on the other. But prominent geologists in India, Middlemiss, Hayden, Holland and others, classed the whole of the Po Series, including the plant-beds, as Middle Carboniferous.[42] I had myself accepted this view of the Geological Survey, till in 1929 Professor Gothan insisted that the plants definitely indicate a Lower Carboniferous age. Since then independent grounds have been advanced in support of the same conclusion.[15, 124b]

THE GLOSSOPTERIS FLORA.

Towards the end of the Carboniferous period an extensive glaciation in the southern hemisphere killed out most of the older vegetation, while the contemporary northern flora, familiar to us in the Coal Measures of Europe and North America, appears to have flourished in a tropical climate. In the wake of the climatic revolution in the south there appeared an almost entirely new type of vegetation, which is known as the *Glossopteris* flora, after its predominant genus.

The relatively small number of species in this flora, the scarcity of arboreous forms, and the presence of sharply marked growth rings in the few trees that are known, are all facts which support the idea of a relatively cold temperate climate,[132] though in the later stages (Barakar, Damuda) the climate must have been sufficiently warm to maintain a vegetation rich enough to yield thick seams of coal. In contrast, the northern coal-measure flora was much richer in species, and it included many arboreous forms, with poorly marked or no growth-rings. An interesting fact about the northern Lower Permian flora is the apparent abundance of tree-ferns (*Psaronius*, *Zygopteris*, *Asterochlœna*, *Tubicaulis*, *Grammatopteris*) which often possess a felt of adventitious aerial roots [95a, 95b]; and the fact that among these roots we frequently meet with evidence of rich epiphytic growths (especially of zygopterids upon *Psaronius* trunks) [88] reminds one of the tropical rain forests of the present day.

The *Glossopteris* flora has been discovered in such far scattered countries as India, Australia, South Africa, South America and Antarctica. Yet it is so uniform in its general character and at the same time so distinct from nearly all the northern floras of the time, that it must have been evolved on a distinct continent. There is ample evidence that at this period of the earth's history a great mediterranean ocean, the Tethys, separated the northern botanical provinces from a southern continent, of which India formed an integral part, its northern coast roughly following the trend-line of the present Himalayan Range. To this hypothetical southern continent geologists have given the name Gondwana Land.

It was in India that the first traces of the *Glossopteris* flora were discovered, now well over a hundred years ago ; and it was here that the idea of a distinct southern continent first arose. Since then volumes have been written about Gondwana Land and its flora but it still intrigues us with its problems of geography and climate, and the distribution, affinities and geological relations of its flora. It still remains the centre of interest in Indian palæobotany.

Relation with the Carboniferous Ice Age.

A much debated question is the exact relation of the Gondwana flora to the Ice Age from which it emerged. All the new geological data that have come to hand from Kashmir, the Salt Range and Central India are consistent with the old view (which fits in with the palæobotanical facts) that India was under ice during the Upper Carboniferous and in any case not later than the Lower Permian.[116] As regards the relations of the flora to the climate, we have long suspected that in India, as in South Africa, the *Glossopteris* flora had already come in before the land was free of ice and that it even includes some hardy remnants of the pre-glacial vegetation.[80] It is difficult to visualize the extent to which such a widespread glaciation must have affected the pre-existing flora, but it can hardly have destroyed all traces of life over the whole of Gondwana Land. Nor was the whole of this enormous area under ice at one and the same time. Even in intensely glaciated regions today there are localized asylums with microclimates of their own, the importance of which in the survival of species through a glacial period has to be recognized[12, 132a, 139, 154, 155].

There is nothing inherently improbable in the idea that the early phases of the *Glossopteris* flora overlapped with the latter end of the glaciation. Even today a rich vegetation (though sometimes only an ephemeral one) is known to flourish in many parts of the world in the vicinity of glaciers and ice sheets. We see this in parts of Greenland,[128, 132] in Norway,[41] Novaya Zemlya,[139] New Zealand,[132] Alaska,[41] Chile[41] and, nearer home, in the Himalayas.

Coming after a great Ice Age, the *Glossopteris* flora was bound to be very distinct from the contemporary floras of the northern hemisphere, and also from the pre-glacial vegetation in the south. But the source of origin of so many entirely new forms of life, both plants and animals, remains a mystery. They seem to appear simultaneously over the whole of Gondwana Land: in South America, South Africa, Australia, and Antarctica; also in India. They could scarcely have come from any other part of the world, there was hardly any country left for them to come from: unless it was some remote parts of the Antarctic continent itself, most of which is still beyond the reach of geological investigation. The only conclusion is that these new forms of life, which are so characteristic of Gondwana Land, must be essentially an indigenous product, that is, of southern origin. They appear to have evolved rapidly from the meagre flora and fauna which had survived the Ice Age. It would almost seem that exposure to the rigours of the climate had quickened the pace of evolution, as if by inducing saltations on a large scale: a sort of natural vernalisation, affecting not only the individual life-cycle, but the rate of evolution of species, possibly through aberrations in the nuclear cycle. A palæobotanist has perhaps no right to indulge in speculations in cytophysiology, but I am advised that the idea is not quite an absurd one. The only alternative would seem to be the spontaneous origin of a number of entirely new and independent lines of evolution.[129] One must admit that this idea of occasional snaps in the life-lines of the organic world seems almost forced upon us by great palæontological breaks such as that at the base of the Gondwanas. But it appears that during recent years considerable progress has been made in our knowledge of the effect of the environment upon the structure of the nucleus. While the extinction of individual lines of descent must be accepted as a settled fact, it may be that the climatic revolution, from which the *Glossopteris* flora emerged, itself supplies the clue to the apparently sudden arrival of so many new forms of life.

The *Glossopteris* flora must have had its roots somewhere in the past, and as I suggested several years ago,[80] at least some of the lines of descent can be traced back into the pre-glacial flora.

In connexion with the climatic relations of the *Glossopteris* flora a discovery of unusual interest has been made within the last few weeks at Kathwai, in the Salt Range. At a level only about 20–25 feet above the glacial bed, Mr. E. R. Gee had collected, a couple of years ago, a small flora including *Glossopteris*, *Gangamopteris* and other Lower Gondwana plants. Until recently we had thought this to be the earliest known Gondwana flora in India. By macerating bits of the carbonaceous shale Miss Virkki[141] of Lucknow obtained, among other things, a great variety of spores, some simple, others provided with wings. In all at least two dozen species of spores were recognized, and a fact of special interest was that some of them (figs. 1, 2) recalled a two-winged pollen grain, *Pityosporites antarcticus*, which Professor Seward[127] had described in 1914 from a remote part of Gondwana Land, within a few degrees of the South Pole. Although badly preserved and more than once called into question this solitary Antarctic pollen grain has recently acquired a new interest. At first taken for a microspore of a pine or podocarp, it is now regarded as more probably belonging to *Glossopteris*,[131] a genus which is known from two localities in Antarctica. Similar spores have recently been found in association with *Glossopteris* in South Africa, and within the last few days Miss Virkki has discovered hundreds of 2-winged spores (figs. 3, 4) in a piece of shale from New South Wales crowded with leaves of *G. Browniana*.[142] So we now know spores of the same general type from such far scattered parts of Gondwana Land as India, Australia, Africa and Antarctica. The age of the Antarctic pollen grain is not definitely known : it may be much younger than the Salt Range spores ; but the resemblance is noteworthy.

Kathwai was evidently worthy of a special visit, to see if a still earlier flora than that discovered by Mr. Gee could not be found, and Miss Virkki's trouble was amply rewarded. From two new horizons only about 1½ feet and 4½ feet above the boulder bed, in the same geological section that Mr. Gee had examined, she obtained a further lot of spores, and some of these are identical with those associated with *Glossopteris* and *Gangamopteris* higher up in the section.

As a caution it must be stated that the exact height of these new horizons above the glacial bed is still somewhat in doubt : Mr. Wadia tells me that the basal zone above which the 1½ feet were measured is not the original boulder bed, but a resorted deposit of glacial débris overlying the true Talchir horizon. He adds, however, that the difference in age between the original moraine and the resorted deposit cannot have been considerable.

Now, the time interval represented by the overlying 1½ feet of sediments must have been so short that the lowermost of the spore-bearing horizons may be taken to be approximately of the same geological age as the glacial bed. And if some of the winged spores really belonged to *Glossopteris* or *Gangamopteris*, a possibility which, as we have seen, is well worth considering, it would mean that here, in the Salt Range, at least, the *Glossopteris* flora was practically contemporaneous with the Carboniferous Ice Age. To prove that the flora actually co-existed with the ice it only remains to demonstrate these spores within the glacial matrix itself, and I think the facts at hand fully justify the expectation that this will be done. An investigation of the spore content of the glacial matrix, not only in the Salt Range but in other parts of Gondwana Land, is thus full of interesting possibilities.

Another interesting fact is that among these forerunners of the *Glossopteris* flora at Kathwai were also a large number of winged seeds or fruits, referable to the genus *Samaropsis*, whose parent plants are still unknown. Whether some of these spores and seeds actually belong to Glossopterids is still an open question, but the fact that a large proportion of them are winged is perhaps not altogether without significance : they were the flying harbingers of a new flora which probably invaded India before the land was free of ice.

It is only fair to say, however, that there is another way of looking at these facts. Dr. C. S. Fox,[15, 16] who has made a careful study of the Lower Gondwanas, believes that in India the *Glossopteris* flora came in long after the ice had disappeared : even if plant remains were to be found preserved within the boulder bed they would not indicate contemporaneity with the ice, because according to him these materials were old moraines, re-sorted and deposited by streams long after the glaciation had passed away.

I confess it is not easy to share this view. In Kashmir, where we witness the same sort of association of modern forests and glaciers, probably most of the moraines in which the trees are rooted have undergone re-sorting since they were first deposited by the receding glaciers of the Pleistocene. The time interval between the modern flora and the end of the Pleistocene is relatively so small that a similar difference in age would scarcely count in the geological time scale of the Permo-Carboniferous : after all, we have scarcely yet emerged from the Pleistocene Ice Age, even in India !

Quite apart from these climatic questions, intensive work on the spore content of rocks has its importance in other directions. To the palæobotanist, spores are often of great diagnostic value, and a single tiny fragment of shale may reveal a dozen species of a flora hitherto unsuspected. Although the parent plants of these spores may be unknown, and they may not all belong to a local flora, they all have the same value to the geologist who is interested in the correlation of strata in scattered parts of the world, or of seams within a single coalfield. In fact, the ease with which spores travel across space should make them particularly useful as zone fossils. Quite recently Dr. Erdtman[13a] has published an interesting account of a varied flora of spores recovered from the atmosphere over the Atlantic Ocean. He also refers[13b] to other literature on the subject of spore dispersal. The recent works of Naumova[53] and Luber[50], presented before the last Geological Congress at Moscow, are significant in this connexion. The microscopic investigation of Indian coals is still almost a virgin field, but its possibilities in Indian economic geology are evident from the recent work of Dr. A. K. Banerji.[1]

Modern mycologists in Europe, America and India are familiar with the way in which the spores of fungi travel for hundreds of miles with the prevailing winds and carry plant disease to distant regions. We therefore need not be sceptic if a palæobotanist were to claim that two given fragments of rock from distant parts of the world are of the same geological age if they both show the same kinds of well-defined spore forms.

Botanical affinities of the Glossopterids.

We may now briefly consider some purely botanical aspects of the *Glossopteris* flora. If I may anticipate what I am going to say, recent work in India and elsewhere seems to bring this flora into the foreground of that old question, the origin of the flowering plants. We are still ignorant of the affinities of those large, simple, net-veined leaves, referred to *Glossopteris*, *Gangamopteris* and other genera, which formed the most distinctive feature of this widespread flora. We have long suspected that *Glossopteris* was not a fern but a seed-plant. Professor Walton [150] has shown that its rhizome contains bordered tracheids of the gymnosperm type. On the other hand the fact that the epidermis of *G. angustifolia* [76] resembled that of angiosperms suggests an examination of other species in which the cuticle is preserved.

Do the Glossopterids after all belong to that ancient southern stock from which the flowering plants are supposed to have arisen? They were certainly a virile race, for they not only dominated the southern flora but spread far and wide into the northern continent of Angara Land, where Zalessky [159, 160, 161] and others have recognized several types of leaves recalling familiar Gondwana forms. Harris has referred to *Glossopteris* a broad net-veined leaf from the Rhaetic of Greenland, and a similar leaf from the Mesozoic of China has been figured by Gothan and Sze under the name *Anthrophyopsis*. Then there is the widespread Jurassic plant *Sagenopteris*, formerly taken for a fern but now known to belong to a totally different group, the Caytoniales, possibly intermediate in position between the gymnosperms and angiosperms. [32, 33, 106]

Sagenopteris, by the way, or leaves strongly recalling *Sagenopteris*, have quite recently been recognized in our Rajmahal flora by Mr. Jacob [45] of Lucknow. If these leaves really belong to the same genus as those from the Jurassic of Yorkshire, this is the first discovery of Caytoniales in India. In the same flora Mr. A. R. Rao [57, 58] has found a large number of 2-winged pollen grains, and some of these again may possibly belong to Caytoniales, though this is still an open question. The spores are of at least two different kinds; one kind is contained in pollen sacs of the coniferous type, but others were found scattered in the rock matrix and their affinities are still unknown.

Now, the fact that both *Sagenopteris* and *Glossopteris* are closely associated with those peculiar double-winged pollen grains of the *Pityosporites* type, seems to lend significance to the outward resemblance between these net-veined leaves, both of which, moreover, recall those of dicotyledons. At the same time we must exercise caution before accepting any real affinity between these two genera till we know more about their reproductive organs.

My object in mentioning these facts here is by no means to suggest that *Glossopteris* gives the clue to the origin of angiosperms, but only to show how this question tends to get pushed further and further back in the geological scale. Not so long ago, the earliest undoubted angiosperms known to us were from the Lower Cretaceous rocks ; but structurally they were already so highly evolved that it was obvious the group must have had an origin long before the Cretaceous. Various discoveries before and since have suggested that angiosperms already existed in the Jurassic period. It is true that the Caytoniales, once claimed as true angiosperms, now appear in a different light.[32, 33] But we at least seem to have here, in this Jurassic group, an inkling of one of the ways in which the closed ovary may have originated.[106, 119] And if *Sagenopteris* was related to *Glossopteris*, which is pre-eminently a Palæozoic genus now generally regarded as a Pteridosperm, we can imagine the trend line of evolution traced back into one of the earliest groups of seed plants that we know.

I confess I do not yet see my own way clear. In dealing with such highly theoretical questions caution is necessary at every step. For, if palæobotany teaches us one thing more forcibly than any other, it is the wisdom of the open mind. Latterly some of us have been more impressed than ever with the older theory that the angiosperms arose from the Bennettitales or some closely allied group.[92, 104] But of this we shall have more to say at a later stage.

Botanists have long been familiar with the anatomy of many members of the coal-measure floras of Europe and North America, preserved in coal-balls. In the contemporary Lower Gondwana flora, almost the only known petrifactions belong to the artificial genus *Dadoxylon*. A sideritic block from the Parbelia Colliery in Bengal recently described by Mr. H. S. Rao[60] shows the nearest approach to a coal-ball yet discovered in Gondwana Land. It raises hopes of further discoveries which may yield data concerning the anatomy of some of the characteristic members of this flora.

Relation with the Palæozoic Angara flora.

About 14 years ago several large petrified trees were unearthed near Asansol[78]: they all seem to belong to one species, *D. Zalesskyi*,[91] which shows a few interesting points of resemblance with the Siberian form *Mesopitys Tchihatcheffi*. This resemblance of a Gondwana plant with a member of the northern flora is not an isolated fact. In the Palæozoic flora of Siberia the existence of a gondwana element has long been suspected. Although the occurrence of *Glossopteris* and *Gangamopteris* has been disputed *, and the gondwana affinities of the northern flora may have been over-estimated, some degree of affinity is generally admitted, and it demands explanation because the barrier of the Tethys sea separated the two botanical provinces. In order to explain this affinity palæobotanists have long believed that some means of communication for land plants must have existed across the sea. Among others, Professor Zalessky [159] insisted that either the marine barrier was bridged over by an isthmus or a dense archipelogo must have served as stepping stones for Gondwana plants migrating to the north. This supposition, it must be noted, was made 20 years ago, solely as an inference from the palæobotanical facts. Since then the independent field work of Mr. Wadia in Kashmir and of Professor Mushketov † north of the Pamir plateau has proved that during Late Palæozoic times there was actually a series of land patches dotted over the Tethys sea in this region. These islands may well have served as a means of intermigration between the two floras.[112]

Field work by members of the Geological Survey of India in Kashmir on the one side and in N.E. Assam on the other has helped to define somewhat more precisely than before the northern coastline of the old Gondwana continent. Recent work has shown that the edge of Gondwana Land in this region, roughly parallel to the main Himalayan arc, was upheaved with the late Tertiary mountain building movements. Near Gulmarg in Kashmir, the highly tilted *Gangamopteris* beds, exposed at an altitude of about 13,600 feet, are probably the most elevated Gondwana plant beds known. The fact that Kashmir lay on the main route of migration between the Gondwana and Angara continents invests the flora of this region with special interest: and this flora, as suggested several years ago,[80] shows a somewhat closer affinity with the Siberian flora than does that of the peninsular Gondwanas.

Relation with theories of continental drift.

Let us now turn to another aspect of palæobotany as an aid to geology: I mean the relation of palæobotany to certain theories of earth movements, particularly large horizontal movements of the continental type. Not very long ago geologists favoured the idea that a great portion of the old Gondwana continent was lost in the sea through the foundering of extensive land bridges. This idea is by no means obsolete now, but it no longer seems to have the same hold as it did even ten years ago. Data from several directions seem to be converging to the bold hypothesis, with which the name of Alfred Wegener is more closely associated than any other, that India and the southern land blocks were once directly connected together, and have since drifted apart, somewhat like the fragments of a disrupted iceberg. This view does not necessarily preclude the idea that the marginal portions of some of these continents may have been lost through block faulting.

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* Quite recently Professor Zalessky has described further specimens from Russia which he definitely assigns to these two genera.[160, 161]

† I wish to record my sincere thanks to Professor D. Mushketov for an interesting letter (14th January, 1937) in which (in reply to an enquiry) he drew my attention to his work of 1928 in Eastern Ferghana. Between the meridians of 70° and 75°E. he found evidence of many isolated dome-like elevations, only 10 to 50 miles apart, which would presumably suffice to account for the suggested migration.

A bird's-eye view of the four great Permocarboniferous floras does indeed seem to support the drift theory on common-sense grounds.[102, 104a, 105] Thus the familiar Coal Measure flora of Europe and North America lies sundered by the North Atlantic Ocean. The *Gigantopteris* flora of China and Western North America seems as if it was split in two by the Pacific. The *Glossopteris* flora lies in far scattered lands in the southern hemisphere; but curiously enough, its Indian section seems to have been pushed far up into the north, and is dovetailed in a most puzzling manner with the *Gigantopteris* flora of China, which has very little in common with it. Lastly, in Kashmir the *Glossopteris* flora reaches to within a few degrees of the Angara flora in Russia, which is also on the whole distinct from it, although at the same time it shows some undoubted Gondwana affinities.

I would hardly be justified, even if I had the time, to venture upon a discussion of Wegener's theory except in so far as it concerns the geographical position of India. The late Professor Wegener was mainly concerned with movements which involved a *drifting apart* of continental blocks. I shall deal briefly with what may be regarded as a complementary counterpart of Wegener's theory: a *drifting together* of continents once far separated by the ocean.[105, 107, 114]

According to Wegener India during the time of the Gondwana glaciation lay far to the south, next to Madagascar, wedged in between Africa on the one side and Australia on the other. Since then it is supposed to have drifted to its present position north of the Equator, so as to bring the Gondwanas to within a few degrees south of the Angara flora. We have just seen, too, that between these two floras there are some elements in common; and these appear to have crossed the ocean barrier by means of an archipelago, of which geological evidence exists. At first sight, therefore, the relations between the two botanical provinces seem to be easily and satisfactorily explained.

The matter is, however, not quite a simple one. Professor Halle[31] has raised the pertinent objection that if during the Permian period India lay near Madagascar, while Siberia was near the Permian equator,the distance between the two regions would probably have been too great to be easily explained by migration across an archipelago, particularly as the two floras would in that case have been in such different climatic zones that effective migration is difficult to imagine. These difficulties are no doubt serious if they are based upon correct premises. But we are not bound to accept the details of Wegener's reconstruction of Pangæa. Towards the end of the Permian, when the disruption was well on the way, the distance between the two floras may have been much shorter than during the glaciation.

Another objection, and one that at first appeared a more serious one, is based on the work of geologists and oceanographers who have investigated the Arabian Sea and the structure of its coastline. The recent John Murray Expedition, led by Colonel Sewell,[156] found evidence which, it was suspected, might go to prove that this sea covers a foundered land-bridge once connecting India with Arabia and Somaliland. The simple coastline of the Arabian Sea coast, among other facts, no doubt suggests block faulting on a large scale; and the idea of a sunken land-bridge seemed at first to be supported by the fact that specimens of basaltic rock had been dredged up from the bottom of the sea. But Dr. Wiseman[156a] reports that at least some of these samples of basalt from the Carlsberg Ridge differ chemically from the Deccan traps and from other plateau basalts : 'there is strong evidence that they are of submarine origin and do not represent sunken remnants of any former land area '.

The true value of the accumulated data has still to be assessed. At the same time, as we shall see presently, the history of the Arabian Sea, as revealed by these investigations, contains nothing that is inconsistent with Wegener's main idea of the northward drift of India. The faulting just referred to was probably due to forces connected with the Late Tertiary movements that resulted in the uplift of the Himalayas. It therefore does not come into the evidence concerning the much earlier history of Gondwana Land. It probably indicates that a much larger block than merely the Indian peninsula was involved in the northward drift. Nor is it necessary to assume with Wegener that India originally lay quite so far south as Madagascar.

The net result is that you cannot get away altogether from the idea of continental drift, although you may have to couple it locally with the idea of the submergence of large tracts of land through faulting.

But with all this we cannot claim that the problem of the southern element in the Siberian flora is settled. The final solution lies in the lap of the future. Professor Jongmans is even prepared to believe that the gondwanoid forms in the Siberian flora arose independently in the northern continent.

But parallel evolution on such a large scale scarcely seems credible.

Professor Halle [31] is probably right that the Gondwana affinities of the Angara flora are not so close as was originally claimed. Some day, let us hope in the near future, a critical comparison of the two floras will show these affinities at their true value. But, in any case, even Professor Halle does not deny that the resemblances are there and that they demand explanation. At the present moment the only explanation seems to be that some means of communication across the Tethys must have enabled the two floras to intermigrate. The Gondwana flora of Kashmir which probably lay across this route of migration thus acquires a special importance from our present point of view. The migration theory at least has the merit that it was in the field long before Mushketov and Wadia brought forward geological facts in support of it. The Late Palæozoic archipelago across the Tethys, between India and Siberia, which Zalessky [159] postulated in 1918, may therefore well be claimed as a geological prophesy based on purely palæobotanical grounds.

I should now like to place before you another instance in which speculations based solely on palæobotanical grounds have found confirmation at the hands of geologists and have thrown light upon phenomena of tectonics, palæogeography and ancient climates.

Already in 1927 Professor Halle [30] had noticed the peculiar geographical relations between the *Glossopteris* flora of India and the Far Eastern *Gigantopteris* flora which extends as far south as Sumatra, like a wedge driven into Gondwana Land from the north. He acutely remarked that this 'abnormal north-south direction of the boundary line between the two floral regions . . . . may be found to be in some way connected with the tectonic features'. And he added that 'in the first place one might think of a connection between the eastern part of the Himalayan geosyncline and the sea in the region of the present Bay of Bengal'. Now, on a variety of grounds which we need not repeat here, the *Glossopteris* flora is generally regarded as a cold temperate flora,[132] while the *Gigantopteris* flora, like the closely allied coal measure flora of Europe, is believed to have flourished in a moist tropical climate. We know of no other two other floras, living or extinct, which are floristically and climatically so distinct, and yet lie thus side by side on the map : crossing the same latitudes along a north-south front of well nigh two thousand miles. East of the Sumatra wedge the trend of the boundary between the two floras is still obscure : if the reported occurrence of *Glossopteris* in N.W. Borneo is confirmed the boundary here turns sharply to the N.E. between Borneo and Siam ; if not, it either sweeps eastwards [105, 107], generally following the line of the Malayan arc, and possibly extending as far as New Guinea ; or, as Professor Jongmans

(1937, p. 361) * has recently suggested, it crosses Borneo in a S.W.-N.E. direction.[46a]

These peculiar geographical relations first came into full evidence when it was discovered that the essentially northern *Gigantopteris* flora extended as far south as Central Sumatra, just across the present Equator, as if cutting the *Glossopteris* province of Indo-Australia into two.

Here, then was a plantgeographical problem of the first magnitude. Whether this southern *Gigantopteris* salient was a broad sweeping arc or a sharp wedge, there was no doubt of a most unusual dovetailing of the two floras which was difficult to reconcile with the sharp contrasts between them. The palæobotanist saw no possible explanation of the phenomenon unless he made a series of large geological assumptions. These assumptions were, firstly, that the two land areas on which these very distinct floras were evolved were originally far apart, with a barrier between them effective enough to prevent any large intermingling of land plants : and such a barrier could only be a wide ocean ; secondly, that the two provinces then lay in very different climatic zones of the globe : in other words, that the ocean barrier ran more or less in an east-west direction, unlike the present north-south boundary between the two regions ; thirdly, that the two land masses drifted towards each other, respectively to the north and south, so as to narrow down the intervening barrier ; fourthly, that owing to resistance offered by the sharp promontory of Gondwana Land in N.E. Assam, the free Far Eastern limb of the *Gigantopteris* province assumed a flanking movement round that angle ; fifthly, that there may be a structural geological continuity of the mountain ranges round the Assam salient, that is, a syntaxial angle essentially of the same sort as Mr. Wadia [144] had already shown to exist round the N.W. promontory in Kashmir.

It was only natural to relate the latter phases of these horizontal movements with the vertical movements which resulted in the formation of the mountain ranges of northern India and Burma, roughly marking the old Gondwana coastline in this region. And if these upheavals resulted from one and the same series of orogenic forces, even though at slightly different times in India and Burma, it was rational to define the Himalayas so as to include not only the two limbs of the re-entrant angle in Kashmir, but the whole series of festoon-like loops of mountains from our N.W. Frontier, possibly even Baluchistan as far as the Malay Archipelago.[105, 107, 114]

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* Professor Jongmans (1937, fig. 2) reproduces in a revised form a map which I had published in 1935 ; but as I then suggested the exact position of the boundary in this region must depend upon more definite data. I am not aware, for example, that the S.E. portion of Borneo, which Professor Jongmans definitely includes in Gondwanaland, has yielded evidence of a *Glossopteris* flora or other data pointing to Gondwana conditions.

In connection with the suggested flanking movement of the *Gigantopteris* province round the pivot of the Assam promontory, the fan-like radiating drainage of S.E. Asia, with so many large rivers bunched together opposite the N.E. corner of Assam, appeared to assume a peculiar significance. It seemed as if this movement at least fitted in better with that ingenious modification of Wegener's drift theory, namely Gutenberg's idea of continental spreading.[28, 29] Indeed, according to Professor Kenneth Mason most of the rivers in that difficult region of deep gorges are probably true strike rivers, and Mr. Evans's [14] recent geological work has shown that this is a region of intense compression; also that there is an actual geological continuity in the mountains round the Assam angle, such as we had already postulated.

It is difficult on this occasion to dwell longer on this fascinating subject, which is of interest alike to the botanist, the geologist and the geographer. Suffice it to say that to those palæobotanists who had something to do with the elaboration of these ideas it is a matter of some considerable satisfaction that on the whole their views have been found to fit in with the geological evidence. That some of these ideas had already occurred to geologists, notably to Mons. Fromaget,[18, 19] Director of the Geological Survey of Indo-China, only enhances the value of the independent palæobotanical evidence. It turned out, indeed, that some prominent geologists, Kropotkin and Gregory, Ting and Grabau,[140] as well as that well known botanical explorer, Capt. Kingdon Ward, had advocated views opposed to those suggested by the palæobotanical facts.[151, 152, 153] But the evidence subsequently adduced by Mr. Wadia,[147] Mr. Evans [14] and others has strongly upheld our conclusions.

Capt. Ward finds that the modern flora of the E. Himalayas is continued eastwards from Assam into the mountains of China, whereas the flora of the Arakan Yoma is different. This fact, among others, has led him to conclude that the Himalayas are continued eastwards across China, almost as far as the Pacific coast. But in the region of China where the supposed eastward continuation of the Himalayas would lie there is no evidence of any marine sediments of the Himalayan type. That region was a land area inhabited by the *Gigantopteris* flora. It is not surprising that the modern flora of the longitudinal range of mountains in Burma is different from that of the Assam Himalayas, for these lie on a different latitude and are subject to different meteorological influences.

If the history of this part of the earth's surface has been as I have just outlined, it will be clear that at least those parts of Burma lying east of the Arakan Yoma have no geological affinity with India. They have been brought into their present position in comparatively recent times by horizontal forces which were ultimately responsible for the uplift of the Arakan Yoma.

Decline of the Glossopteris *flora.*

Parsora stage. During the Permo-Triassic transition the *Glossopteris* flora suffered a decline, and in the Parsora beds in Rewah (Central India), which some geologists still prefer to class as the Middle Gondwanas,[143] a flora of a considerably younger aspect than that of the typical Lower Gondwanas has been collected. The main features of this flora are, firstly, the absence of most of the characteristic members of the *Glossopteris* flora, although at least a few of them, notably *Noeggerathiopsis Hislopi,* still survive, and secondly the abundance of forked leaves of the *Dicroidium* type. This is a widespread southern genus which in other parts of Gondwana Land is regarded as marking the Triassic period.

The age of the Parsora beds has been much disputed. In 1917 Dr. Cotter classed them as Rhaetic, and in 1921 I accepted this correlation.[75] In 1926 I was inclined to regard the flora as older, and provisionally referred it to the Upper Trias.[80] In 1932 Professor Seward, who examined a further collection from the same region, suggested that the flora was still older, at least as old as the Lower Trias and more probably Late Permian.[130] While palæobotanical opinion during the past two decades has thus tended to place the Parsora beds lower and lower in the geological scale, Dr. Fox,[15] in his recent important work on the Gondwana System, has placed them as high as the Jurassic; he regards them as only slightly older than the Rajmahal series.

The whole question is still open, because some recent collections added by Mr. N. K. N. Aiyengar and by Mr. S. D. Saksena still await examination. Dr. Fox is probably right that in Dr. Cotter's list of this flora, which I had accepted on his authority, species from two distinct horizons were mixed up. But even after allowing for this, and considering only the specimens from Parsora, Chicharia and other northern localities which Dr. Fox assigns to the Upper Gondwana, the flora appears to me to be distinctly older than the Jurassic.

MESOZOIC FLORAS.

We have already seen that Eastern Burma was probably not a part of Gondwana Land. This being the case, it is to be expected that the fossil floras of that region would be more akin to those of the Far East than to those of India. From the Loi-an series of beds in the Southern Shan States, adjoining China, a Rhaetic or Jurassic flora chiefly comprising of ferns and conifers has been collected. Only the conifers [82, 89] have yet been examined, and these on the whole seem to be allied to Chinese forms rather than to members of the Gondwana flora.

But we are now entering upon an era when the regional contrasts between floras were again breaking down. Indeed the flora of the Jurassic period includes so many species which apparently had a worldwide distribution that the problem is how this fact is to be explained if the earth was divided then, as it is now, into distinct climatic zones. The same question applies to the 'cosmopolitan' floras of the Devonian and early Carboniferous periods. The Jurassic flora of Graham Land, far away in the southern hemisphere, on the edge of Antarctica, seems to be more nearly allied to that of our Rajmahal Hills in Behar than to any other known flora of that age; and the Rajmahal flora in turn includes a number of species closely resembling Jurassic plants from England and Scotland. A small flora from Afghan-Turkistan, now being described by Mr. Sitholey,[135] includes some forms allied to Jurassic plants from Angaraland, and others recalling species form the Upper Gondwanas.

Whether any theory of continental drift will ever help to solve this problem of 'cosmopolitan' floras it is too early yet to say. Perhaps some day we shall have enough data to be able to correlate at least the major climatic oscillations in geological time with large geographical changes possibly due to drifts connected with a shifting of the earth's axis. This may give the clue to some of the anomalies of the distribution of extinct floras which puzzle us today. But such an attempt here would lead us too far into speculation.

The flora of the Rajmahal Series.

I shall now devote a few words to the progress made in recent years in our knowledge of the Indian Jurassic floras, particularly that of the Rajmahal Hills. This was the first Indian flora to be described in any detail, and it is a classical flora because it has served as a basis for botanical comparisons and geological correlation for many allied floras in other parts of the world. It is therefore important to define as precisely as possible the structure and affinities of the plants, as well as the geological age of the plant-bearing beds, which are exposed in numerous places scattered over an area of nearly 4,000 square miles.

Silicified plants from the Rajmahal Hills.

Until recent years our knowledge of this flora, like that of most others of the same age, was practically confined to leaf impressions, and no fresh collections had been reported since Feistmantel described the flora over half century ago. Latterly the Rajmahal Hills have received a good deal of attention.[55-58, 90, 92, 103, 117–119, 137, 138] Many new plant-bearing localities have been found and large collections have been added.[26] An event of special importance to palæobotanists is the discovery of several localities which have yielded abundant silicified remains. This has already enabled us to study the anatomy of familiar members of the Rajmahal flora such as *Tœniopteris*, *Ptilophyllum*, *Williamsonia* and others. It has helped us at least partly to meet two of the main difficulties with which the student of fossil plants has to contend, namely, the fragmentary nature of the material and the fact that it too often consists only of impressions, which are notoriously unreliable as guides to affinity. These petrifactions, moreover, have made it possible to recognize, as parts of one and the same plant, leaves, stems, flowers and other detached organs which have long been under distinct generic names.

As one instance I may mention the leaf impressions to which McClelland, I think in the very first annual report of the Geological Survey of India, as long ago as 1850, gave the name *Taeniopteris spatulata.* In the midrib of these leaves, now available in the petrified state, a series of mesarch bundles of the modern Cycadean type were noticed a few years ago (fig. 5).[93] A detailed investigation of the material was entrusted to Mr. A. R. Rao,[55, 56] and his study of the epidermis opens up the question whether this plant, originally taken for a fern, was a true cycad, or one of the Bennettitales. In the same rocks occur a number of short shoots covered with rhomboid leaf scars, on which a horizontal row of 6 to 8 vascular bundles are marked. These shoots were previously mistaken for cones, but are now under suspicion as the parent axes on which the *Tœniopteris* leaves were attached. Similar shoots, now discovered in the petrified state, reveal a ring of five tangentially flattened bundles round a central pith ; these bundles give off multiple leaf-traces such as might well have supplied the expanded leaf base of a *Tœniopteris.* What is more, Mr. B. P. Srivastava [137, 138] has discovered in the same rocks a number of larger stems, referred by him to a new genus *Pentoxylon* ; and these also generally contain five tangentially flattened primary steles round a pith. In these thicker stems each primary stele has secondary wood all round, but this wood shows an unusual mode of development. It is enormously developed on the side turned towards the pith so that as the stem grows in age the five steles tend to grow mostly on their inner sides.

On the evidence before us we thus have strong grounds for the belief that the leaves, which have been known to palæobotanists for almost ninety years under the name *Tœniopteris spatulata*, were leaves of the deciduous type, borne upon short cylindrical shoots, and that these in turn were the younger branches of *Pentoxylon* stems. Now the wood of *Pentoxylon*, curiously enough, is of the compact, coniferous type, with narrow medullary rays and bordered pits, so that if the correlations here suggested are well founded, we have an interesting combination of cycadean and coniferous features. At the same time the structure of the wood and the mode of branching of the steles recalls that seen in the problematical genus *Rhexoxylon* which is known from two distant regions, South Africa and Antarctica.

These facts will show how the discovery of these petrifactions has affected the original notions concerning the affinities of one of the first species of fossil plants ever described from this country. The true affinities can only be discussed when the reproductive organs are discovered, and it may well be that some seed bearing cones (*Conites Pascoei* Sahni[89], *Carnoconites* Srivastava[138]) which in places occur plentifully in association with the leaves, were the fructifications of *Pentoxylon*. It is not impossible that this interesting type will turn out to be a representative of an entirely new and synthetic group of plants combining cycadean, Bennettitalean, coniferous and other features. I must not further speculate upon the results of this work, in which Mr. Rao and Mr. Srivastava are still engaged at Lucknow, but enough has been said to show the far-reaching implications of the discovery of these petrifactions.

Let us consider one more example of a similar kind. Several years ago Professor Seward showed that the Bennettitalean leaves long known as *Ptilophyllum* cf. *cutchense*, previously only found detached, were borne upon stems of the type to which he had given the name *Bucklandia indica*. He surmised that the flowers of this plant were probably of the *Williamsonia* type, of which several species were already known from the Jurassic rocks of India though none of them had been found attached. Now, among the petrifactions recently discovered was a *Williamsonia* flower borne upon the tip of a short vegetative axis, and this axis agrees with *Bucklandia indica* in the anatomy of the wood and leaf bases. These facts have provided the main data for a reconstruction of what is now the most completely known of all Williamsonias, *Williamsonia Sewardiana.*[90] This flower, by the way, very closely resembles a species from the Jurassic of Scotland, described by Professor Seward as *W. scotica*, so that we have here a striking link between two geographically far separated floras.

A fragment of petrified wood, found long ago at an unknown spot in the Rajmahal Hills, has turned out to be a fossil of more than ordinary interest. It has been given the name *Homoxylon rajmahalense.*[92] The interest of this fossil lies in its anatomical resemblance with the wood of some fossil cycads on the one side and with that of some modern dicotyledons, referred to the primitive group of the Magnoliales, on the other. It thus seems to lend support to the idea that at least one line of angiosperms was derived from some gymnospermous group related to the Bennettitales.

Homoxylon was at first taken for a piece of conifer wood, because it was a homogeneous wood devoid of true vessels, the chief woody elements being tracheids. But the structure of the medullary rays was different, and the sculpturing of the secondary wood showed a range of variation, from the scalariform to the round bordered type, which was unknown in the conifers.[92, 104] These features were to be found only in two circles of affinity: firstly, in the Jurassic group of the Bennettitales which is strongly represented in our Rajmahal flora; and, secondly, in the living homoxylous genera *Drimys*, *Zygogynum*, *Trochodendron* and *Tentracentron*,[22. 23] which also have a primitive floral organization, recalling that of the Bennettitales. Soon afterwards a fossil wood *Tetracentronites*,[52] came to light from the mesozoic of Greenland and this, as the name implies, resembles the modern *Tetracentron*.[96] Whether *Homoxylon* was the wood of a primitive angiosperm or whether, as Dr. K. M. Gupta has suggested, it belonged after all to one of the Bennettitales—and this is a possibility always to be kept in mind—the theoretical interest of this solitary fragment of wood is obvious.

There is, of course, no suggestion of anything like a direct connexion between the modern Magnoliaceæ and the Bennettitales as we know them today. All that is implied is that in its descent the modern group seems more nearly related to the Bennettitalean line than to any other. Because latterly the structure of the epidermis has risen into prominence in phylogenetic studies, Mr. H. S. Rao[62] undertook at my suggestion to examine the epidermis of modern Magnoliales and particularly that of the homoxylous genera, and, as you will learn from himself today, although the Magnoliales as a whole seem to be a mixed group from the epidermal stand-point, all the homoxylous genera examined (*Trochodendron*, *Tetracentron* and *Drimys*) constantly show the same type of stomatal structure as that characteristic of the Bennettitales. On the whole, therefore, the evidence does not contradict the idea of a common origin for at least the homoxylous Magnoliales and the Bennettitales.

Among other Rajmahal petrifactions is a slender stem, (*Lycoxylon indicum* Srivastava[138]) containing a stele with 16 protoxylems placed at the ends of woody plates, exactly as in a modern *Lycopodium*. This may be the petrified form of *Lycopodites gracilis*, the surface impression of a shoot first described about 75 years ago. The silicified stems and petioles of several ferns have been discovered. One or two of these are attached to pinnæ, so it should be possible to correlate the anatomy with species known from impressions.

Among impressions newly discovered perhaps the most interesting is *Rajmahalia paradoxa*,[118, 119] a concave plate of rhomboid form bearing a mosaic pattern of scars, some rounded, others polygonal—suggesting that it is probably a new type of Bennettitalean flower. Some of the other fructifications recently discovered in the Rajmahal Hills are *Ontheodendron,*[117] probably one of the Araucarineæ ; *Nipaniostrobus* A. R. Rao,[58] a conifer having ovules with peculiar curved micropyles ; *Masculostrobus rajmahalensis,*[58] a male cone containing two-winged pollen grains of the type familiar in pines and podocarps ; *Sakristrobus,* a new genus of entirely unknown affinity, found by Mr. Jacob[45] in association with the *Sagenopteris*-like leaves already mentioned; and hundreds of seeds, probably of *Nilssonia.*

Time does not permit anything like an adequate summary of this work, which is still being carried on by Messrs. Srivastava, Gupta, A. R. Rao, Jacob and others. But enough has been said to indicate the significance of the results, achieved and expected, from an intensive examination of this rich flora, the only known Jurassic flora that has yielded so much information about its anatomy.

Age of the Indian Upper Gondwana floras.

Before leaving the Rajmahal flora I should like to draw your attention to certain doubts that have recently arisen concerning the ages of our Upper Gondwana floras. The plant-bearing beds are exposed in far scattered areas. Apart from the Rajmahal Hills in Behar, they occur in Cutch and Kathiawar, in the Central Provinces, and in a string of outliers along the east coast, from Orissa as far as Ceylon.[133, 46] A few fossil plants of Upper Gondwana age occur also in the north, near Shekh Budin in the N.W. Frontier Province.

With the exception of the Rajmahal, none of these floras have yet been critically examined since they were first described, well over half a century ago. In their general composition, with a preponderance of ferns, cycads and conifers, and with not a single species characteristic of the Cretaceous, they all strike one, so far as we know them at present, as good Jurassic floras. At the same time we cannot yet say whether the sequence in which the Rajmahal, Kota, Jabalpur and Umia stages are generally placed by geologists is fully supported by the plant evidence.

The Rajmahal flora was originally placed by Feistmantel in the Lias, but in 1913 Professor Halle gave reasons for regarding it as Middle Jurassic. About eleven years ago Dr. du Toit suggested that the base of the Rajmahal series may possibly extend into the Rhaetic or even into the Keuper. On the other hand Dr. L. F. Spath,[136] on the evidence of some cephalopods in the Upper Gondwanas of the Madras coast, has not only assigned these beds to the Lower Cretaceous but concludes that all the Upper Gondwana beds of India are at least as young as the Lower Cretaceous.

If we are to take the plant-fossils as a guide, then at least so far as the Rajmahal flora is concerned, there does not seem to be much to say for the Cretaceous view. A species of *Proto-*

cyathea, recently described from the Sakrigali beds by Mr. Jacob,[44] may at first seem to indicate that here the series passes up into the Cretaceous. It is true this genus was not so far known in the Jurassic; but it is only a form genus, based upon casts of the stems of tree-ferns. All it indicates is the occurrence of Cyatheaceous ferns with a large multiple leaf-trace. Leaf impressions referable to this family are already known in the Jurassic. Mr. Jacob's species, moreover, being new to science,cannot by itself serve as an index of geological age, and it is associated with typical Rajmahal species of cycads and conifers: *Ptilophyllum acutifolium, Nilssonia Morrisiana, Brachyphyllum expansum*, and other forms.

This is all that the plants have to offer in support of Dr. Spath's view, and you will agree this is not worth much. A point could perhaps be made for an Upper Jurassic age if we knew definitely that *Williamsonia scotica*, with which the Rajmahal form *W. Sewardiana* is closely allied, is definitely an Upper Jurassic species, but at present even this is uncertain. On the other hand, if the Rajmahal stems known as *Pentoxylon* have any real affinity with the genus *Rhexoxylon*, which again is uncertain, we may have some remote indication in favour of Dr. du Toit's view that the Rajmahal series may extend back into the Trias.

I am not competent to express an opinion on the nature of Dr. Spath's evidence from the Madras Ammonites, and how far it is justifiable to apply that evidence to other areas. But if that evidence is conclusive and if it must also apply to the Rajmahal beds, then here, at least, is a real bone of contention between the palæobotanist and the palæozoologist. We were so long accustomed to look upon the Rajmahal flora as Jurassic that we had nearly forgotten there was any other viewpoint but the palæobotanical. But I am one of those who believe that between the testimony of fossil plants and the testimony of fossil animals there is, and there ought to be, no real conflict. Nor do I believe that where the field relations of the beds are clear they should ever contradict the fossil evidence. Apparent contradictions there are many, as we shall see in our joint discussion [124a] on the subject this afternoon. But these contradictions, I venture to think, are nearly all of our own making. They are born of errors due to a lack of data or to our own imperfect understanding of the data.

As regards the floras of the Kota, Jabalpur and Umia stages, which are much less known, it would be rash to express definite views till our revision of these floras is finished. The Umia plant-beds were originally classed as Jurassic, and the flora did not seem to contradict this view. But some years ago we were told that these freshwater deposits are interstratified with marine fossiliferous beds homotaxial with the Wealden. If this is an established fact we must look for a Lower Cretaceous element in the flora. At the present moment no undoubted

Lower Cretaceous forms are known from these beds but some recent collections have not yet been examined.

A Wealden flora in India.

Quite recently Dr. Heron and Mr. P. N. Mukerjee have discovered what I believe is the only land flora in India definitely known to be of Cretaceous age. This comes from the Himmatnagar sandstone in the Idar State in Western Rajputana. In this small collection it was interesting to find two widespread genera of xerophytic ferns, *Matonidium* and *Weichselia*, showing for the first time the extension of the Wealden flora into India.[111] The *Matonidium* is a new species closely related to *M. Goepperti*, which is more common in the Wealden rocks than in the Jurassic. The other genus is represented by the well known form *W. reticulata*, a leading species of the Wealden flora. In the Nubian sandstone of Egypt this fern is associated with some undoubted dicotyledons. It would be interesting to look for the remains of flowering plants in the Himmatnagar sandstone, and for *Weichselia* in the Umia beds. It would be interesting also to know if the Barmer sandstone in Rajputana, in which angiosperms are known to occur, is of the same age as the Himmatnagar beds. The floras of the Bagh beds, and of the Lameta beds, which underlie the great Tertiary volcanic series in the Deccan, are still entirely unknown.

Cretaceous marine algæ from Southern India.

In the marine limestones of the Niniyur group in the Trichinopoly district Professor L. Rama Rao [64] of Bangalore discovered an algal flora of great interest, a description of which we owe to Professor Julius Pia. The plants have been referred to several existing families of sea weeds. The majority of the species being new to science the flora by itself does not throw much light upon the age of the limestones, but on the whole the evidence at hand suggests that these plants flourished in a transgression of the sea towards the close of the Cretaceous period.

TERTIARY FLORAS.

Tertiary (and ? post-Tertiary) algæ.

So far as we know this is the first record of algal remains from the Cretaceous rocks of India. But in the early Tertiary beds, deposited along the shores of the great Nummulitic sea, we have evidence of marine or brackish-water algæ from a number of scattered localities. From the Ecoene of Sind Professor Walton [149] described a *Triploporella*, a member of the modern family Dasycladaceæ. From the Nummultic beds of Cherrapunji in Assam the late Professor H. C. Das-Gupta [6] assigned to *Lithothamnium* some algæ associated with diatoms and Foraminifera. The reference to the modern genus should be regarded as provisional. He also mentions the occurrence of similar algæ in Navanagar, Porbunder and elsewhere in Western India, in rocks apparently of much younger ages. A further collection from Assam, recently sent me by the Director of the Geological Survey, seems to include a calcareous algal flora comparable in importance with that discovered by Professor Rama Rao in Southern India. Fossil algæ have also been found in strata of debatable age in Waziristan and in the Kohat district on the N.W. Frontier.

Characeous fruits, often loosely described under the modern genus *Chara*, but more safely assigned to *Gyrogonites*, were first reported from Tertiary beds in the Deccan just over a hundred years ago,[51, 3] but they have never been adequately described. In recent years they have been collected in several new localities, notably near Sausar in the Chhindwara district,[99] and again in the Rajahmundry area.[66] In the latter district (near Pungadi and Dudukur) the Mysore geologists Narayana Rao and Sripada Rao have discovered several genera of marine algæ, including *Acicularia*, *Neomeris* and, strangely enough, a *Holosporella*[68] apparently identical with an Upper Triassic species from the Burmo-Siamese border.

Evidently, the algal remains of the Indian strata offer a vast field of research, of which only the fringe has yet been touched. It is not improbable that their investigation will yield results of importance both to the botanist and the stratigraphical geologist.

The flora of the Deccan Intertrappean Series.

During the times when these algæ flourished in the estuarine and coastal waters of the Deccan, the peninsula witnessed an era of unprecedented volcanic activity. Lavas of a fluid type welled up from fissures in the earth and overflowed the land, while rains of volcanic ash repeatedly overwhelmed the vegetation.

An observant traveller landing at Bombay, who crosses the Western Ghats by the Great Indian Peninsular railway, cannot fail to notice the low, flat-topped hills which dominate the landscape as far as Nagpur and beyond. These terraces represent the weathered surfaces of these lava flows or 'traps' at different levels in a great basaltic series, aggregating several thousand feet in thickness. Here and there, between the traps, are preserved lenticles of freshwater sediments, occasionally mixed with beds of volcanic ash. These so-called Intertrappean deposits appear to have been mostly laid down in small temporary lakes which must have been formed at intervals by the damming up of streams by intermittent outbursts of lava; and they contain a most valuable record of the floras and faunas of those times.

The Intertrappean flora is indeed one of unique interest, because nearly all the major groups of the plant kingdom are represented, and the plants are mostly silicified, their structure being often exquisitely preserved. It is therefore worth while to devote a few words to an account of this important flora, and of the way in which it has influenced the views of geologists concerning the age of the Deccan lavas.

Age, early Tertiary: decisive evidence of plants.

Interest in the geology and palæontology of the Deccan dates back through well over a hundred years. It is associated with the names of some of the earliest geologists who worked in this country: Malcolmson,[51] Hislop and Hunter,[38–40] Carter [3] and others. Of the large collection of fossils that we owe to the labours of these pioneers, the animals have been described, but the plant remains were never adequately examined. For over 70 years they were forgotten, scattered in various museums in India and abroad. Many of these historic specimens, alas, can no longer be traced and are apparently lost to science. The long years of oblivion suffered by these collections were particularly unfortunate, because the clear and direct evidence of the age of the Deccan Traps, which this flora provides, was temporarily lost sight of. This evidence was in their time appreciated by Malcolmson, Hislop and others, who compared the flora in a general way with that of the London Clay, already known from Bowerbank's work.[2] Down to 1871 Thomas Oldham [54] also upheld the view that the Traps were of early Tertiary age. But soon afterwards serious doubts arose among geologists as to the wisdom of relying upon fossil plants in fixing the ages of strata. A prolonged and bitter controversy over the ages of the Gondwana floras resulted in a serious setback to the recognition of palæobotany as an aid to stratigraphical geology. For the time being, at any rate, fossil plants were at a discount, not only here but in Europe.

In India the effect of this opposition was particularly severe: the foremost Indian geologists of the day, including such influential men as W. T. Blanford, H. B. Medlicott and the Oldhams, had given the verdict that the evidence of plant-remains was untrustworthy: the palæobotanical witness had to stand down.

It was during this period that the question of the age of the Deccan Traps was reviewed, more than once. The animal evidence, at first thought to support a Tertiary age, now appeared to give no lead in the matter. And the plants, of course, were not to be trusted. There remained only the indirect evidence, firstly, of the underlying Lameta beds whose exact relations with the Traps, by the way, are still unknown; and, secondly, of conditions in other areas, like the West Coast at Surat and Broach and even further afield, in Sind and Baluchistan. Relying upon these data for what they were worth, W. T. Blanford (see under 5) cast his opinion in favour of the view that the Deccan lavas were of Cretaceous age, not Tertiary as the plants had suggested. Whether it was that this indirect evidence was really decisive or whether the Gondwana controversy had turned him against the plants, the fact remains that the Cretaceous view prevailed. Blanford certainly had not much respect for plant-remains. But his judgment in most debated questions was reputed to be so sound that I reckon this was one of the few matters in which he erred. Thirty years ago Sir Arthur Smith Woodward [158] reiterated the old view, this time on the basis of some fish remains from beds then believed to be Lametas but which quite probably were Intertrappeans. But the verdict had been given, and Blanford's view held almost undisputed sway [42, 143] until—shall we say, *the plants came into the evidence once more*. This happened in January 1934, when a preliminary account of the Deccan flora was placed before this section at the Bombay session of the Congress.[98, 99, 100, 120, 123]

Enquiries made during the previous seven or eight years had already led to the recovery of many of the old specimens from various museums both in India and elsewhere. At the same time, fresh collections had been added from a number of new localities by members of the Geological Survey, by Professors Rode, Agharkar and Parija, by Mr. Shukla of Nagpur and by others. Of the new discoveries the most important from the point of view of geological age was Professor Rode's find of an undoubted *Nipadites*, [70, 121] a genus of palm fruits eminently characteristic of the Eocene (fig. 9). Its value lay in the fact that although Hislop [38, 40, 3] had mentioned this genus among his large collection of fruits and seeds, the original specimens had never been described and were no longer traceable.

The detailed investigation of this accumulated material, now being described at Lucknow, will take some time but, as explained, our preliminary survey had already made it clear some years ago that a flora which included *Nipadites*, the familiar water-fern *Azolla*, and, especially, an overwhelming proportion of palms, could not have flourished in Cretaceous times : it was undoubtedly a younger flora.

But this was by no means all. Soon after the first reaction of scepticism [17] was over, fresh evidence from a number of different sources converged in support of a Tertiary age. Messrs. Narayana Rao and Sripada Rao [66] of Mysore announced that in the basal Intertrappeans near Rajahmundry they had discovered the remains of the sea-weed *Acicularia*, essentially a Tertiary genus, as well as several species of stoneworts which they identified with well known Tertiary forms from Europe. Professor L. Rama Rao [63, 65] of Bangalore reviewed the question as a geologist and on the whole favoured the view that 'the Tertiary era had already dawned when the first lavas of the Deccan were poured out'. From the animal side, too, the evidence became reassuring. Professor J. H. Bonnema of Groningen, who kindly examined some ostracod remains at my request, was of the opinion that although their testimony was not decisive, they were more probably Tertiary than Cretaceous. The most encouraging results have accrued from Dr. Hora's examination of the fish-remains,[43] which not only confirmed the plant evidence as to the age, but also supported the idea, suggested by the occurrence of *Nipadites*, and at first received with scepticism by Mr. Crookshank, that at least in some parts of the Central Provinces estuarine conditions must have prevailed. Lastly, Professor V. S. Dubey [11] of Benares wrote that his estimates of the helium content, at least of the basalts in Western India, also indicated a Tertiary age; although, of course, the traps round Nagpur, Chhindwara and Rajahmundry should also be estimated before the evidence from radioactivity can be said to prove that the whole of the Trap series is of post-Cretaceous age. The reason for this caution is that it was from these areas that the fossil evidence was derived, and it is here that the earliest traps are said to be exposed.

Taken as a whole, the evidence was distinctly in favour of the conclusion based upon the plant remains.[5, 67, 115]

Happily, the controversy is now almost laid at rest. Last year, when this question was discussed at our Hyderabad session, we had the gratification to find that some geologists took the lead in upholding the view which had so long remained in the background. In short, we discovered on that occasion, as we have done before and since, that there really is no conflict between the testimony of the rocks and that of the plants or of the animals.

I have gone into the history of this question in some detail—in greater detail, perhaps, than is appropriate to an address—but I thought that no review of palæobotany in India would be complete without a reference to the way in which the study of plant-remains has come into its own. But of this we shall hear more at the discussion on plant and animal fossils which is to come off this afternoon.

Botanical interest of this flora.

Of individual plants of botanical interest in the Deccan flora the number is too large to justify more than a cursory reference. At least in some localities the flora is largely an aquatic one, and, as stated, local estuarine conditions are indicated by the occurrence of *Nipadites*, a fruit closely resembling that of the stemless palm *Nipa fruitcans* which is common in the Sunderbans and other tropical estuaries at the present day. Other palm fruits include one with a trilocular ovary and three large seeds, the fibrous fruit-coat being traversed by longitudinal canals which must have aided dispersal in water.[69, 100, 121] Some of the algæ, as we have seen, were brackish-water or even marine forms. Other aquatic plants are represented by abundant fruits of Charophyta, angiosperm stems with large air-channels and poorly developed wood, shreds of ærenchymatous tissue in the process of decay, associated with fungal mycelia as well as filamentous aquatic algæ apparently covered with minute unicellular epiphytes. Specially interesting, and very common at Sausar, is an *Azolla* [120, 61] whose mega- and microsporocarps, and many free-lying massulæ with their anchor-tipped glochidia, are perfectly preserved ; fragments of leaves and stems, as well as roots covered with root-sheaths, within which a row of papillæ apparently represent young root hairs, can be matched with the corresponding organs of some living species of this water-fern. The name *Enigmocarpon* has been given to a multilocular fruit (fig. 14) of unknown affinity ; [70, 100, 121] it has eight radial septa springing from an axile placenta ; the thick carpel wall consists of spongy tissue well adapted for dispersal by water ; the dehiscence is clearly marked as loculicidal ; the numerous anatropous ovules contain a dicotyledonous embryo. Two species of cardamoms were found (one is shown in figs. 6, 7), and a strange kind of longitudinally ribbed seed has been given the name *Sausarospermum.*[123] *Viracarpon* [100] is a cylindrical aggregate fruit with six-seeded partial fruits crowded round the axis. Two new genera of seed bearing cones,[89] *Takliostrobus* and *Indostrobus*, as well as a new species referred to *Pityostrobus*,[89] show that the conifers were not unrepresented. Dicotyledons are also to be found.[71–72] But by far the commonest plant-remains in this prolific flora are the petrified stems of palms,[87] sometimes with their sheathing leaf bases attached, and often with a mantle of adventitious roots still preserved round the base of the trunk.

Unfortunately, these fragments of palm stems are never found in organic connexion with flowers or fruits, or even with the distal parts of leaves, which might give some clue to their systematic position in the family, for there must be many genera and several tribes of this family represented among the hundreds of specimens collected. In the absence of satisfactory criteria for a natural classification palæobotanists have been forced to group all species of petrified palm wood into the single artificial genus *Palmoxylon.* Of this genus we have now been able to put together, in the course of the last 17 years' work, no less than 45 Indian species,[87, 94, 69, 74] where only three were known before, including one from Ceylon.

The variety of structure shown by these *Palmoxyla* is bewildering. A highly artificial classification, based upon variable features of the anatomy, such as the distribution and form of the fibrovascular bundles, has been adopted, and the danger of creating spurious species is enhanced by the fact that these characters vary in different parts of the same stem.

Obviously, in describing these Indian *Palmoxyla* it was important to compare the anatomy of modern species of palms, with a view to discover, if possible, some more constant and reliable criteria of affinity. There was always the hope that in this way we might be able to link up at least some of the fossil species with modern genera whose place in the family was established on the safer ground of floral structure. The task was a laborious one, because the tissues of the palm stem are notoriously difficult to deal with. But in the hands of Mr. K. N. Kaul of Lucknow, who has evolved his own technique of preparing the sections by grinding,[47] these difficulties have been largely overcome. And what is much more important to the palæobotanist, he has actually discovered a criterion, or rather a set of criteria, which run without any large degree of variation through entire genera. This, of course, is the essence of a natural classification: constancy through groups of generic rank, with variations marking species within the genus. Mr. Kaul will expound his results before you himself this morning, but I may briefly state the main point he has made. The chief basis of his anatomical classification is the ground tissue.[48] Relying upon this basis he has been able to show [49] that the fossil species which I had named *Palmoxylon coronatum* is anatomically a *Borassus*, that my *Palmoxylon mathuri* is a *Bactris* and that my *Palmoxylon sundaram* is a *Cocos*. The work is not yet complete, but it will be agreed that the back of the problem is broken. We should now be in a position to refer at least the best preserved of our *Palmoxyla* to natural genera of palms.

Other Tertiary floras.

I do not propose to detain you long over the other Tertiary floras, of which the remains we find preserved in numerous places, scattered far and wide in the country.[4, 13, 24, 25, 27, 84, 85, 97, 125, 126] I have elsewhere [75, 89] given an indication of the wealth of this material, and of its great interest in connection with the geographical distribution of modern floras.

Apart from the Deccan Intertrappean series, by far the most important of our Tertiary plant-bearing strata are those of the Siwalik System and its equivalents. These are exposed along the foot of the great mountain belt stretching from Sind in the west to as far as Burma in the east, and they correspond in age to the Miocene and Pliocene of Europe. These extensive formations have yielded a rich flora of modern aspect: leaf impressions of angiosperms; petrified wood both of dicotyledons and palms; fruits and seeds. Several of our *Palmoxyla* come from the Pegu and Irrawady series of Burma, which are believed to cover the period from the Oligocene to the Pliocene; both these sseies contain a great profusion of silicified wood, evidently derived from rich forests not unlike those of modern Burma.

The Pliocene upheaval of the Himalayas.

About half an hour back I was trying to show how the study of fossil plants has helped us to visualize horizontal earth movements of large magnitude. Before closing this address I should like to refer briefly to another aspect of geology on which recent palæobotanical work in India has thrown light. I mean vertical movements of the earth's crust, leading to the formation of mountain ranges. We have already seen that the chain of mountain arcs from Baluchistan to the Malay Archipelago replaced a former line of weakness in the earth's crust; and like the seams of a patched up garment it is a raised line. Let us see how the study of fossil floras helps us to understand this most recent of all seams in the earth's crust.

Its relation with the arrival of conifers in northern India.

From a revision of the Indian fossil conifers,[82, 89] undertaken about ten years ago, the striking fact emerged that in the Tertiary flora of northern India and Burma there was no trace whatever of this group of plants. Conifers, as we all know, cover vast areas in the Himalayas today. But even the younger strata of the Siwalik System, which, the geologists tell us, were deposited during the Pliocene, have yielded no trace of conifers. The first evidence of this group appears in the overlying Pleistocene beds in which the characteristic winged pollen of Abietineæ has been recognized. The advent of the coniferous flora of the Himalayas must therefore be placed at a date towards the end of the Pliocene or even later. Now the great majority of Himalayan conifers, the deodar, the spruce, the silver fir, yew, juniper and others are plants of cold or cold temperate climates. It is therefore a plausible idea that the coniferous invasion of India was postponed till the elevation of the Himalayas had provided a climate suitable for the growth of these alpine and sub-alpine plants. And this idea fits in generally with the findings of geologists: the Pliocene was a period of marked orogenic upheaval in the Himalayas, though the final upheavals did not come till the Pleistocene.

PLEISTOCENE FLORAS.

The Karewas of Kashmir.

Let us now follow up the clue a little further and see what the Pleistocene flora has to tell. Perhaps the most fascinating of Pleistocene floras is that of the Karewas of Kashmir,[109] to which Godwin Austen drew attention over 70 years ago. Some of these Karewa beds are richly fossiliferous lake deposits containing a varied assemblage of forest trees and shrubs as well as aquatic plants, frequently associated with fish bones and freshwater shells. They must have been laid down in a vast body of water, possibly a series of connected lakes, covering an area much greater than the present valley of Kashmir. In the valley the beds lie horizontally, as they were originally laid down. But the same strata have been traced in a continuous series up the slopes of the mountains on either side and here they lie tilted towards the valley at angles up to 30 or 40 degrees, the dip gradually decreasing as we approach the valley. Isolated Karewa patches have been found on the N.E. slopes of the Pir Panjal range even at altitudes of 13,000 feet or more.

The Himalayan uplift since the advent of Man.

Within the thickness of over a thousand feet of these strata there are three or four glacial horizons, corresponding to those in the Pleistocene of Europe. The fossiliferous horizons represent only the mild interglacial periods. What is more, at least in one of these interglacial beds, not far from Srinagar, Dr. de Terra has recently found stone implements, apparently marking the arrival of Palæolithic man,[34] and in a slightly higher layer at the same spot were discovered pieces of charcoal, and the clay figure of an ox. It is evident that we are now rapidly getting down to our own times. And who knows but that our present civilization may after all be only an interglacial episode within the Pleistocene !

But I find I am digressing. I must talk about the plant fossils and their connexion with the Himalayan uplift. In a collection of Karewa fossils from near Baramula my late colleague Dr. S. K. Mukerji (see [109]) recognized the leaves of a large number of modern species, while Dr. Wodehouse [157] and Dr. S. C. Varma have identified the pollen grains of several conifers and dicotyledons. To mention only a few of these plants, we have the pine, deodar, spruce and silver fir ; also the oak, willow, poplar, box and rhododendron, as well as aquatic plants such as the water nut (*Trapa*), *Vallisneria* and stoneworts. As for the water plants, the same species still flourish in the lakes and streams of the valley of Kashmir, into which also the leaves of trees from higher altitudes are still being washed down.

The geological interest of these aquatic species lies in the fact that while in the valley, which is only a little over 5,000 feet above sea-level, they live in a mild climate, their fossil remains have been found in the Karewa beds at altitudes where they could not possibly exist today. At Bota Pathri near Gulmarg I have collected fossil fruits of *Trapa* from a height of 9,500 feet, where snow lies for the greater part of the year (figs. 10, 11). The only conclusion is that the Pir Panjal Range has been upheaved through several thousand feet since the time when these plants lived in the great Pleistocene lake of Kashmir.

This conclusion is by no means new. Godwin Austen had already acutely suggested that a great part of the Himalayan uplift had probably taken place since the advent of Man. Indeed the suggestion might even be ventured that Palæolithic Man may have been able to migrate freely between India and China by the direct route across the region of the Himalayas which at that time may not have been high enough to form an effective barrier.[110]

THE RELATION BETWEEN PALÆOBOTANY AND ARCHÆOLOGY

The fact that some of these recent palæolithic finds in northern India are geologically datable provides a valuable link between the time scales of the palæobotanist on the one side and of the archæologist on the other. And one might perhaps with advantage venture a plea for a closer co-operation between workers in these two fields. For instance, a visit to the prehistoric mounds at Harappa last year brought to light some charcoal of the wood of a conifer, showing that already at that early date (at least 2,500 B.C.) our people were in touch with the forest wealth of the Himalayas, possibly through the medium of the river Ravi. In the Khokrakot mound at Rohtak, in the Jumna valley,[108] which is now being excavated, some terra-cottas, after chemical treatment like fossil incrustations, have revealed the cuticles of paddy husk. In some of these cuticles the form of the cells and the distribution of the stomata can be made out; and the form of the spikelet is also clearly impressed upon the clay, with which the husk was mixed. Some of these impressions bear a remarkable likeness to *Oryza sativa* var. *plena*, which is distinguished by the presence of more than one grain of rice in each spikelet (figs 12, 13). If the date of these terra-cottas can be fixed archæologically, it may show that this interesting variety of rice was already known to the Yaudheya tribes in the rich province of Bahudhāñaka, just about 2,000 years ago.

Investigations on these lines promise much towards an elucidation of the origin of many of our cultivated plants. For, according to the latest researches of Professor Vavilov (whom we are particularly sorry not to find amongst us today) it would seem that it is in this country that this debated problem is most likely to find solution.

CONCLUSION.

LADIES AND GENTLEMEN,

In the brief course of this hour we have seen a passing show of our fossil floras, from the earliest down to the most recent. We have seen that the study of these floras is not only interesting in itself, or to the botanist alone; but that through this study the botanist has been able to repay at least a part of the debt that he owed to the geologist. We have seen, too, that a critical study of archæological plant-remains is likely to yield data of value to the historian. With the inevitable specialization of our age continually threatening to divide us, it is no small gain to Science in India that the brief period of seventeen years that we have just reviewed has brought about an era of understanding and co-operation between us, with still higher promise for the future. For the true aim of all Science is to unite, not to separate.

But if I were to tell you what it is that has impressed me most, amongst the individual results achieved through this concerted work between scientists in different fields, then I would say that it is the realization of the great instability of our earth. Entire continents are drifting. Whole mountains are upheaving : almost before our very eyes. For have we any reason to believe that these movements came to a stop with the arrival of our own species upon the earth ? It is true we have at present no means, in India, of measuring the progress either of the horizontal or of the vertical movements that have led to the birth of our unbelievably youthful Himalayas. But with the advent of the wireless the technique of recording the position of points on the earth's surface, particularly of their meridia, has become so perfect, that it should be possible for a man, within the brief span of his active life, to detect any drift movements, well beyond the range of experimental error. We may therefore hope that accurate readings of longitudes will some day yield direct proof that the distance between, say, Western Baluchistan and Eastern Burma is steadily diminishing. For the present, however, the absence of critically placed recording stations is a practical difficulty in the way.

As for the vertical movement of the Himalayas, we have seen that recent work in India in which, I am glad to be able to say, palæobotany has had its share, shows beyond doubt that this uplift is largely a matter of the human epoch.[35–37, 7–10, 145, 109, 110] Indeed all the most recent investigations go to show that these mountains, far from being an inert mass, are more like a living, moving, responding organism.

But, after all, is there anything in this fleeting world of ours that is really at absolute rest ?

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EXPLANATION OF PLATE.

FIG. 1. *Pityosporites* sp. Lower Gondwana (Talchir stage) of Kathwai, Salt Range, Punjab; horizon 1½ ft. above the Talchir Boulder Bed. × 380.

FIG. 2. *Pityosporites* sp. Locality and horizon as above. × 380.

FIG. 3. *Pityosporites* sp. Newcastle Coal Measures, (Permocarbonif.) Newcastle, N.S.W. From a piece of shale crowded with *Glossopteris browniana* Bgt. × 400.

FIG. 4. *Pityosporites sewardi* Virk. Locality and horizon as above: from the same piece of shale. × 400.

FIG. 5. *Tæniopteris spatulata* McCl. Rajmahal stage (Jurassic); Loc. Nipania, Rajmahal Hills. Transv. sec. of petiole (diagrammatic). *cpx* centripetal xylem, *cfx* centrifugal xylem, *px* protoxylem, *ph* phloem. × *ca.* 35.

FIG. 6. *Amomocarpum affine* sp. nov. Deccan Intertrappean series (Eocene). Loc. unknown. Hunter and Hislop Coll., Brit. Mus. Impressions of two fossil fruits. Nat. size.

FIG. 7. *Amomocarpum affine* sp. nov. A plasticine cast of the same specimen. Nat. size.

FIG. 8. *Elettaria Cardamomum* Mat. & White, a living specimen for comparison. Nat. size.

FIG. 9. *Nipa* (*Nipadites*) *Hindi* (Rode) Sahni, Deccan Intertrappean series (Eocene) of Mohgaon Kalan, Chhindwara Dist., C.P. Transv. sec. of drupe. Nat. size. (Coll. K.P. Rode.)

FIGS. 10, 11. *Trapa* sp. Upper Karewa series (Pleistocene) near Bota Pathri, Pir Panjal Range, Kashmir, alt. *ca.* 9,500 ft. Fruit, nat. size. 10a, spine with barbs, × 4½. (Coll. B. Sahni.)

FIG. 12. *Oryza sativa.* Impression of spikelet on baked pottery, showing form of paleæ and epidermal cells. The actual impression is concave, but it appears convex in the photograph. Surface find from the Khokrakot mound, Rohtak, Jumna valley. × 4·3. (Coll. B. Sahni.)

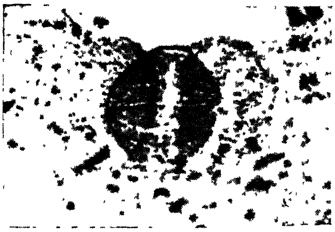
FIG. 13. *Oryza sativa* var. *plena.* Modern, for comparison with the fossil impression in fig. 12. × 4·3.

FIG. 14. *Enigmocarpon Parijai* gen. & sp. n. Deccan Intertrappean series (Eocene) of Mohgaon Kalan, Chhindwara Dist. C.P. Transv. sec. of 8-loc. fruit, with thick spongy wall; dehiscence loculicidal. × 2.

FIGS. 1–4 after Miss Virkki; the rest are original.

PLATE 2

SAHNI : Recent advances in Indian Palæobotany.



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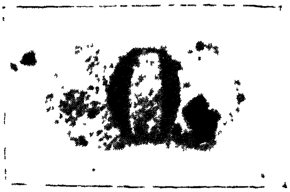
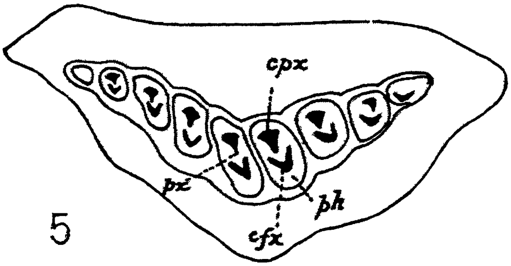


2

3

10*a*

4



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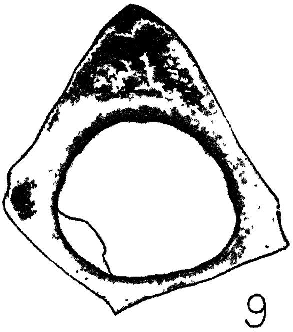

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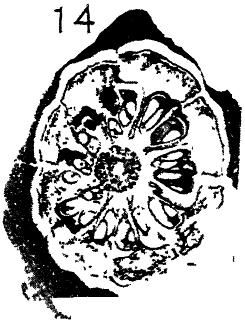

14

SECTION OF ZOOLOGY

President :—G. MATTHAI, M.A., Sc.D., F.L.S., F.R.S.E., F.N.I., I.E.S.

Presidential Address[1]

ZOOLOGY AND ITS ADVANCEMENT IN INDIA

At the outset I have to express my thanks to the authorities of the Indian Science Congress Association for asking me to preside over the Section of Zoology at its Silver Jubilee Session. This is an honour renewed—since 1920 when I was called upon to act as Chairman of the Section of Zoology and Ethnography in the unavoidable absence of the sectional President of that year and again in 1923 when the tenth Indian Science Congress met at Lucknow—to the School of Zoology in the Panjab University, that has contributed not a little to the progress of zoological knowledge in India, and has sent its sons during the past 25 years to fill eminent places in this country for advancing zoological research and directing the organization necessary for the promotion of that research in all its aspects.

For this reason, and because we are this week celebrating the Silver Jubilee of the Indian Science Congress that has consistently given stimulus and encouragement to zoological research in all parts of this country, I have thought it fit to address you on the subject of Zoology and its Advancement in India.

When the Indian Science Congress was founded in 1914, there seemed to have been only four centres where zoological research was being carried on, namely, Madras, Calcutta, Lahore and Allahabad. To-day there are organized Departments of Zoology in several University centres in India. Considering the financial difficulties in this country the progress that zoological research and organization has made has been most gratifying. While in 1914 there were barely half a dozen Indian zoologists engaged in research work, there is to-day a band of well-trained devoted research-workers in this country, with not a mean record of published contributions towards the advancement of zoological knowledge.

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[1] The information contained in this address has been collected from published papers and from zoological colleagues in India.

Judging from the printed proceedings of the first three sessions of the Indian Science Congress held at Madras, Calcutta and Lucknow, no presidential addresses seemed to have been delivered when the Section of Zoology met in succession under the chairmanship respectively of the late Dr. J. R. Henderson, the late Dr. N. Annandale, F.R.S. and Dr. W. N. F. Woodland. At the fourth session held at Bangalore in 1917 Sir Ramunni Menon, the President of our Section, then designated as the Section of Zoology and Ethnography, in opening the proceedings 'disavowed any intention of giving an introductory address' and the few remarks that he made filled but one paragraph. The printed proceedings of the fifth Indian Science Congress held at Lahore in 1918 contained the record of the first presidential address delivered before the Section of Zoology and Ethnography on a special branch of Zoology, viz., Ichthyology. In the presidential addresses that followed the themes selected were general, historical, ecological or on special groups or special problems. Of the three eminent zoologists who were called to fill the office of General President of the Indian Science Congress, the late Sir A. G. Bourne, F.R.S. at the fourth Session held at Bangalore in 1917 dealt with science in general in his presidential address. The late Dr. N. Annandale, at the eleventh session held at Bangalore in 1924, and Lt.-Col. Seymour Sewell, F.R.S., at the fourteenth session held at Lahore, in 1927, spoke on Evolution, the former from the ecological point of view and the latter from the standpoint of Experimental Zoology.

In his presidential address before the Section of Zoology of the eighth Indian Science Congress held at Calcutta, in 1921, Dr. F. H. Gravely dealt with the history of Zoology in India and Ceylon since 1659. It is not, therefore, necessary to traverse the ground already covered in that address. We shall confine our attention to what has been accomplished since the foundation of the Indian Science Congress in 1914, more particularly since 1921. At the tenth Indian Science Congress held at Lucknow, in 1923, I ventured to address the Section of Zoology on 'Oceanographical Investigation with special reference to the Indian Ocean', summarizing the history of the various methods in oceanographical research and of the attempts at exploration of the Indian seas. This was followed up at the twentieth session held at Patna, in 1933, by Prof. R. Gopala Aiyar in his presidential address before the Section of Zoology on 'Some aspects of Marine Biological Research'.

The investigation of the Indian Ocean with a view to a proper understanding of its Marine Biology was conducted, since the first meeting of the Indian Science Congress, mainly by the R.I.M.S. 'Investigator' (till 1926) and the John Murray Expedition (1933-1934) under the direction of Lt.-Col. Seymour Sewell. Previously the 'Sea-lark' Expedition had surveyed the Western Indian Ocean, south of the Maldives, more particularly the islands of the Chagos Archipelago and the Mascarene region (during 1905-1906 and 1908-1909). The work of the 'Sea-lark' Expedition was mainly concerned with problems relating to coral reefs and atolls and their Biology, and was a continuation of a previous study of the Maldives and Laccadives. Deep-sea exploration was not part of its programme. The R.I.M.S. 'Investigator' concentrated its work in the Andaman Sea and the Bay of Bengal. The recent work of the John Murray Expedition was in the region of the Arabian Sea, not covered by the 'Sea-lark' Expedition, to the north of the Chagos Archipelago and the Mascarene region, extending to the south and south-east as far as the Seychelles, Maldives and the Chagos Archipelago, and to the west as far as the south-east coast of Arabia and the East African Coast, north to the Gulf of Aden and the entrance to the Red Sea and as far as the Gulf of Oman opening into the Persian Gulf. The study of the Deep-sea Biology of this region was assisted by physical, chemical, hydrographic and topographic investigations. The Survey of India collaborated with the John Murray Expedition in the cruise down the Maldives for making pendulum observations with a view to determining the nature of the foundations on which the Maldives and Laccadives are situated.

[1] The faunistic evidence, particularly Mammalian, appears to be against the probability of a previous land connection of the Andamans and Nicobars with the mainland. It also appears that the Andaman Sea was at one time like a comparatively shallow brackish water lake into which flowed the rivers of Southern Burma, and consists at present of a large basin of sea-water extending down to 2,000 fathoms and two much smaller basins to the north-west with a maximum depth of 1,000 fathoms, and that the Andaman-Nicobar Ridge is connected to the north with the Arakan Range of Upper Burma and to the south with Sumatra and Java, the islands themselves being the highest peaks of a mountain, belonging to the Alpine-Himalayan system, which subsided beneath the surface of the sea, leaving channels connecting the Andaman Sea to the Bay of Bengal. There appears to be also evidence of a comparatively recent upheaval which seems to have been due more to the corresponding fall of sea-level than to actual subsidence of land, a process that appears to have been general in the tropical seas. Around these islands are flourishing coral reefs which extend much more on the west than on the east side, as is generally the case with coral growth in the Pacific and Indian Oceans. The coral banks to the west of the Andamans probably constitute a barrier reef extending from Lat. 13°40′ N. down to Lat. 10°26′N., of a total

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[1] *Vide* 'Geographic and Oceanographic research in Indian Waters', by R. B. Seymour Sewell, C.I.E., Sc.D., F.R.S., Parts I–VIII in Memoirs of the Asiatic Society of Bengal, 1925–1935.

length of about two hundred miles with a channel, 40 fathoms deep, intervening between the reef and the coast, and with seaward steep of 250 to 300 fathoms, there being more regular submarine contours on the north and east of the Andaman Sea than on the west. It appears also that the constitution of the bottom-deposits of the Andaman Sea and the Bay of Bengal is due more to the chemical and physical conditions of the upper layers of the sea-water than to the calcium carbonate dissolving more rapidly from the deposits.

The work of the R.I.M.S. 'Investigator' has extended our knowledge in regard to variation—seasonal as well as daily—in the air temperature over the open waters of the Indian seas, to the east (Andaman Sea and Bay of Bengal) and west (Gulf of Manaar and the Laccadive Sea) of the Indian Peninsula, in the time of occurrence of the diurnal maximum temperature, in the wind force, in the humidity of the atmosphere, and in the amount of rainfall.

A study of the temperature of the coastal water of the Andaman Sea indicated that there was a yearly double-oscillation in the surface temperature of the sea similar to that of the air temperature, that the daily range of temperature and the time of occurrence of the maximum temperature of the surface water was subject respectively to seasonal and monthly variation, that in the case of the air-temperature there was correlation between the mean temperature, average daily range of temperature and the time of occurrence of maximum temperature, that the temperature relationship between the surface water and the air was liable to variation. There was also evidence indicative of a correlation between the rise and fall of the tide and of the salinity and density of the surface water, of seasonal variation and periodic oscillations in salinity and density (the former manifesting itself in a yearly double-oscillation) and finally of the existence of a binodal 'seiche' in each of the two axes of the Bay of Bengal as shown by the salinity of the surface water fluctuating periodically.

Somewhat analogous results were obtained by a study of the surface water of the open Indian seas with regard to variations in temperature, there being a double-oscillation in the seasonal variation and in the mean daily range of temperature comparable to those of the air, and with regard to correlation between the monthly mean and the maximum daily range of temperature, with certain differences in the different regions of the Indian seas. It was also seen that, as in the case of the supernatant air, so in the surface water of the open sea, average temperature variations, daily range of temperature and the onset of maximum temperature were correlated. The relationship between the temperature of the sea-surface and that of the air varied in the course of the year and over the Indian seas, the temperature difference depending mainly on variation in the wind-force in the Indian seas generally. The salinity of the surface water is subject to daily double-oscillation, which undergoes seasonal alteration as, during monsoon months, dilution takes place by rain-water or by an increased volume of water flowing into the sea from the larger rivers. It was also found that there was a daily, in addition to a yearly, double-oscillation in the wind-force in the open Indian seas, causing the deeper water to rise up and be mixed with the surface water. Such a vertical movement of water would influence the correlation in the temperature of the sea and the air, and would modify the salinity and density of the surface water.

In the Indian Ocean, as in other great oceans, there is always a vertical circulation of the layers of water, caused largely by differences in temperature and salinity. It has been shown that in the Indian Ocean, more particularly in the Laccadive Sea and the Bay of Bengal, there are at least four more or less horizontal layers of water, with different temperatures at different depths, extending from the bottom Antarctic drift to the surface water that is constantly being diluted by the out-flow of river-water : (1) an uppermost surface layer characterized by high temperature and low salinity which flows towards the north-east or towards the south-west according to the monsoons, (2) a layer of water from the polar region, 600–700 fathoms deep, flowing mainly towards the north, (3) a layer of low salinity, between 700–1,100 fathoms flowing towards the south, (4) the lowermost layer, which is the Antarctic bottom drift, with a northerly direction. The iso-thermal lines show a rise from the Maldive archipelago to the Andaman and Nicobar islands. With regard to the iso-halines in the Indian seas, it has been noted that in the Laccadive Sea, north of the equator, water of over 35·0 salinity exists in Long. 74°–79°E. down to a depth varying from 328 fathoms in Long. 74° 45′E. to 1,094 fathoms in Long. 76°47′E. In the Bay of Bengal, water of the same salinity occurs in Long. 88°E. from 109–219 fathoms, in Long. 96°–97° E. at a depth of 820 fathoms, the salinity decreasing to 34·8–34·7 at lower levels.

The average temperature of the sea-water varies slightly from 28°·31C. at the surface to 26°·75C. at a depth of 25 fathoms. Lower down the temperature of the sea-water falls rapidly to over 3°C. in each 25 fathoms, thus at a depth of 125 fathoms the average temperature is about 13°C. A discontinuity zone is thus postulated at depths with a fall of temperature of over 3°C. in an interval of 25 fathoms.

Of the equatorial surface currents in the Indian Ocean the north equatorial current flows from the Andaman Sea towards the Somali coast, whilst the contra-equatorial current to the south between Lat. 2°–5°S. flows in the opposite direction extending down to a great depth. The north equatorial current is, however, neutralized by the south-west monsoon. The

Antarctic Bottom drift divides in the Indian Ocean into three branches, the western-most branch flows up to the east of Madagascar, the eastern-most moves north, north-west towards the east coast of South India, becoming sub-divided by Carpenter's Ridge, one of the subdivisions flowing between Carpenter's Ridge and the Andaman-Nicobar-Ridge up to Lat. 12°N., whilst the other sub-branch divides again to pass respectively into the Laccadive Sea and into the Bay of Bengal up to Lat. 9°N.

A reversal of seasons is noticeable in the Indian seas at a depth of about 100 fathoms, comparable to the phenomenon that takes place in the temperate seas, November to January being the summer months and the seasonal range of temperature about 3°·5C. Temperature records seem to show that in the Bay of Bengal, from 104 to 2,200 fathoms, there is a double-oscillation in the temperature of the deeper waters, which in the Andaman Sea is delayed by about a month. In the Andaman Sea the temperature below 800 fathoms is influenced by the presence of the volcanic range that runs through it.

The Laccadive and Maldive Archipelagoes which are situated on two plateaux whose depth vary from 1,000 to 1,200 fathoms from north to south, merges at the 1,300 fathom line into a common base connected with Peninsular India to the north, and has a depth of water of over 2,000 fathoms on each side of its southern end. The continental shelf off the west coast of India has a depth of about 100 fathoms, and at one time perhaps formed part of the Indian Peninsula, subsequently sinking beneath the sea by actual subsidence or by rise in the sea level, as evidenced by the faulting along the coast; or may be the result of the deposition of eroded material from the land surface as indicated by certain differences in the different regions. Coral growth occurs off the coast of Ceylon on the comparatively narrow continental shelf. The floor of the Laccadive Sea is said to have considerably subsided in tertiary times. According to Sewell, 'All the evidence that we have been considering seems to indicate that originally between India and Africa lay a connecting mass or series of masses of land forming either a portion of a large continent, namely Gondwanaland, or at a possibly later stage a narrow connecting isthmus, part of the supposed continent of Lemuria, that finally underwent subsidence and was drowned beneath the Indian Ocean, leaving only the topmost peaks as islands. One cannot, however, ignore the suggestion put forward by Wegener in his work on the origin of Continents and Oceans that India and Africa were at one time part of the same land mass and that they have gradually drifted apart' (pp. 436-37). According to the same author, 'A study of the contours of the Laccadive and Maldive regions and of the soundings that have been taken on the two sides, shows clearly that the basis on which these coral reefs and atolls are perched is a magnificent mountain range that at the present day rises at its southern end from a depth of over 2,000 fathoms and that, if we include the Chagos region, extends through a distance from north to south of nearly 1,500 miles. This great mountain chain runs in a nearly north and south direction and as one would expect in a range of this magnitude, exhibits at certain points along its length breaks in its continuity, some of greater extent than others, that are quite comparable to the various passes that one finds in mountain ranges on land. As a result of these breaks, the islands now marking the topmost peaks are divided into geographical groups, each of which is still further subdivided into a series of banks and plateaux' (p. 437). This mountain system is said to have been continuous at one time with the oldest mountain range in India, namely the Aravalli Mountains. The Laccadive-Maldive Ridge was subject to subaerial erosion owing to exposure to the south-west monsoon. As the ridge sank beneath the sea level, marine erosion would transform the ridge into a number of plateaux. These changes apparently took place at the close of the tertiary epoch, and corals began to grow on the eroded plateaux when the glacial epoch terminated. Analogous changes took place in the Bay of Bengal, resulting in the formation of the Andaman Sea bounded to the east by a mountain range which, unlike the Maldive-Laccadive Ridge, was not entirely sunk beneath the sea surface. According to Sewell, the available evidence is 'in favour of the view that the general conformation of the basis on which the present-day atolls and reefs of these Archipelagoes are situated is the result of sub-aerial and marine erosion on a gradually but continually sinking mountain range' (p. 444), whilst Stanley Gardiner had previously accounted for the present condition of the Maldives to submarine erosion extending to a depth of about 200 fathoms brought about by the action of currents, and not due to recent subsidence of land. According to the latter author it was hardly likely that the islands on atolls were formed by the action of wind and waves in piling up sand and coral detritus, but resulted from a slight fall in the sea-level that occurred comparatively recently (about 4,000 years ago). Along the coast and islands of the Indian seas, evidence is forthcoming of a comparatively recent fall in sea-level (15–20 feet), such as exposed masses of dead coral (as in the Mergui Archipelago), elevated sea beach (east coast of India), raised coral beaches, (Andaman and Nicobar Islands), broad flats (Ceylon), raised coral reefs (South India, near Pamban), raised beaches (south-west coast of India). Similar changes in sea-level have also been taking place in the Chagos Archipelago and the Mascarene region.

In areas of coral growth the building up of the reefs and atolls is assisted by the corals themselves and by Nullipores, as well as by coral débris subsequently consolidated into 'conglomerate rocks ' and various kinds of limestone. The deterioration of the reefs is caused by the erosive action of currents and waves and boring organisms such as sipunculids, holothurians, algæ and sponges, by changes in the normal temperature and salinity of the sea-water. Studies on coral reefs have shown that conditions vary in different regions, necessitating the investigation of atolls and reefs with special reference to local conditions. Reef-forming corals cannot grow at a depth greater than 25 to 30 fathoms owing to insufficiency of sunlight in the deeper layers of the sea. In the estuarine region of the Indian seas such as the mouth of the Ganges (Bay of Bengal), and of the Indus (Arabian Sea) reef-forming corals do not occur owing to adverse conditions resulting from the deposition of mud and silt and perhaps also to dilution of the sea-water. In studying coral-reef formations in the Indian seas it is necessary to bear in mind the temperature factor in the deposition of calcium carbonate by the rapid evaporation of sea-water, which assists in consolidating coral débris into coral conglomerate, the importance of encrusting Nullipores such as *Lithophyllum*, *Lithothamnion* in reef-formation, particularly of the outer part of the reef, the value of surface currents in the open seas bringing food material, and of waves in assisting the formation of Nullipores. In the Maldives and Laccadives both sides of the atolls get the benefit of surface currents and waves owing to the north-east and south-west monsoons occurring at different times of the year. Hence coral growth on both sides of these atolls does not present much difference. In the case of any gradual subsidence of land or rise of the sea-level reef corals, by their continuous growth, will be able to keep the reef surface at the level of the sea. If the change should take place suddenly the reefs will become submerged coral banks. Such submerged coral banks are found in the western region of the Indian seas, particularly in the Chagos Archipelago, the Great Chagos Bank being a well-known instance of a submerged atoll with raised margin 5–10 fathoms deep, the central lagoon being 45-46 fathoms deep. One of the reasons (Stanley Gardiner 1930, p. 8), why the submerged coral banks at a depth of more than 10 fathoms are unable to raise themselves up to the sea-level, is because the corals and calcareous algæ are killed by the deposition of amorphous carbonate of lime precipitated from the supersaturated sea-water by chemical action of their chlorophyll on carbon dioxide, neither the movement of waves and currents nor the ciliary action of the coral polyps being sufficiently effective at such depths to remove the calcareous deposit. When the seaward edge of the outer reef of atolls is fully exposed to the action of waves, particularly during the monsoon seasons, there is rich growth of *Lithophyllum* protecting the exposed seaward edge against the continuous action of waves that prevent the growth of reef corals as seems to be the case in the Maldive atolls. The islands on the reef flat of some of the atolls of the Laccadives and Maldives may have been formed by the action of waves in piling up coral débris on the reef-flat, or by elevation of the coral-reefs consequent on a fall of the sea-level, the raised reefs subsequently becoming divided by erosion and by the formation of deep channels as in certain parts of Minikoi atoll, the Laccadive Archipelago and in the North Malos Bank in the Maldives (Stanley Gardiner 1903, pp. 34–36, 149 and 171).

Precipitation of calcium carbonate may take place in various ways, when fresh water from the land supersaturated with lime meets the salt water of the sea, such action taking place between tide levels (Stanley Gardiner 1930, p. 16 and 1931, p. 43), by the action of denitrifying bacteria (Drew 1914), by the action of decomposing organic matter, by the photosynthetic action of algæ and by evaporation consequent on rising temperature.

The seaward side of the islands in the Laccadives and Maldives is being continually eroded by the action (solvent and mechanical) of waves, particularly in the case of those atolls that lie in the direction of the south-west monsoon. In Diego Garcia situated to the south of the equator, erosion has taken place only where the entrance channels pass into the lagoon, since this island is not affected by the south-west monsoon. Comparative absence of erosion on the east and south-east sides of the Laccadive and Maldive atolls probably account for the presence of numerous atolls on those sides. The eroded débris and sand from the seaward face of the atolls is driven over into the lagoon and is deposited on the lagoon floor. This material as it accumulates on the lagoon side begins at a certain stage to undergo erosion. Erosion taking place on both sides would ultimately wipe out the island. It seems to be a common occurrence that coral reefs on the lagoon or seaward sides have a vertical steep. There is abundant coral growth on the inner side of lagoon reefs in the Indian seas, the reef itself sloping to a depth of 1-2 fathoms, then dropping down to a steep which may get undercut by various agencies such as solution, erosion, destruction by boring organisms. The undercutting is perhaps due to certain factors, in the deeper parts of the reefs, that inhibit or retard coral growth, such as lack of sunlight, higher temperature of the sea-water that in high tide flows over the reef-flat down to the lagoon bottom, this water, while deficient in oxygen and food contents, carries products of erosion to the bottom of the lagoon. In the case of atolls lying north to south the upper part of the steep will overshadow the lower region for part of the day, thus adversely affecting coral-growth in the deeper parts. Since the deposition of sand and mud on the upper part of an atoll will be adverse to coral-growth the reef-flat may become discontinuous. In the coral reefs and atolls in the Indian seas where erosion is taking place there are indications of coral destruction on the reef-surface, ultimately resulting in the breaking up of the reefs, a good example of which is the Horsburg Atoll of the Laccadives in which Stanley Gardiner noticed in 1903 (pp. 307–380) disappearance of land on the south and west sides whilst on the north and east sides erosion was actively taking place. Large quantities of débris resulting from the destruction of land has settled on the upper part of the lagoon reef. With the complete disappearance of land on the south and west sides, deposition of silt will no longer take place, and reef building corals could grow on the north and east sides, thus assisting in the formation of a steep. In the larger lagoons the greater part of the bottom is hard, sediment (consisting of reef detritus, skeletal remains of pelagic organisms, and calcium carbonate precipitated from the sea-water) occurring on the floor of the smaller lagoons. In the lagoons both destructive and constructive processes are at work, if the former is more active the lagoon will widen, if the latter process is more rapid the reef will extend into the lagoon and may ultimately displace it. In the Indian Ocean there are several instances of lagoons tending to become shallow towards the windward side (the prevailing winds being mainly the south-west and north-east monsoons). The detritus from the windward reefs tends to get evenly deposited on the lagoon floor by the action of waves and currents, but occasionally may get aggregated on the lee-ward side of the reefs.

With regard to the channels that connect lagoons with the open sea, the deeper ones were probably present from the commencement of the formation of the coral bank, as coral-growth from such depths was impossible, whilst the shallow channels perhaps had a secondary origin by the deposition of detritus killing coral-growth.

[1] Our knowledge of the topography of the western region of the Indian seas has been extended by the recent John Murray Expedition. The Gulf of Aden is 900 to 1,400 fathoms deep, the depth changing abruptly and the central region being characterized by the presence of ridges alternating with troughs. The contours at the western end run from east to west, whilst at the eastern end and in the middle they are from north-east to south-west. The south-westward ridge from Ras Fartak, about 120 miles long, has on it a depth of 700 to 800 fathoms, its eastern side suddenly dropping to over 2,000 fathoms; depth of over 2,700 fathoms (12,000 ft.) has been determined by two soundings towards its north end, the greatest depth so far recorded for the Gulf and the Arabian Sea. A gully runs by the side of this ridge. There is no evidence of the ridge in the centre of the Gulf having any connection with the mainland. In the Arabian Sea and the entrance to the Persian Gulf, between

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[1] *Vide* 'Scientific Reports of the John Murray Expedition', Vol. I, Nos. 2–5, 1935 and 1936, and 'Nature', 1933 (Vol. 131, pp. 640 and 641), 1934 (Vol. 133, pp. 86–89, 669–672; Vol. 134, pp. 685–688).

Khorya Morya Islands and Ras al Hadd, the decrease in depth is rapid between the 1,000 fathom and 500 fathom lines. The decrease to the 250 fathom line is more gradual, then steep to 60 fathoms. There was no evidence of corals in a bottom sample taken from the San Carlos Banks. The Murray Ridge discovered by the expedition 'appears to be the continuation of one of a series of banks that run in a south-westerly direction from Karachi, possibly a submerged connection of the Pab Mountains. It differs, however, in one respect, in that while it appears to be steep to, and uneven on its summit, the others appear to be more in the nature of shelving banks. In longitude 64°E. three separate banks appear. The northern one rises from 1,730 to 964 fathoms and falls to 2,000 fathoms on its southern side, from which the second ridge rises to 790 fathoms. The third bank rises to 413 fathoms, and is probably separated from the second by a depth of about 1,200 fathoms .... The gully of 2,000 fathoms that separates the two northern banks is similar to the one that lies on the eastern side of Murray Ridge. It is the existence of these gullies that make it probable that they are connected, and that the Murray Ridge is a continuation of the northern bank' (Farquharson, p. 50). The Ridge appears to be continued to the south in Lat. 16°N. and Long. 60°E. and ultimately connected with the Carlsberg Ridge in the Indian Ocean. The Makran Basin has a depth of 1,750 to 1,830 fathoms to the north of the line from Ras al Had to the Murray Ridge, has a smooth bottom and bounded on the north (60 miles from the mainland) 'by a barrier that usually rises between 400 and 500 fathoms from the general depth' (Farquharson, p. 51). Between the barrier and the Makran coast there are ridges and valleys more or less parallel to the coast, the depth of the valleys exceeding that of the barrier by 200 or 300 fathoms. The south-eastern boundary of the Makran Basin is formed by banks that extend from Karachi.

The Carlsberg Ridge divides the western region of the Indian Ocean into north-eastern and south-western halves, and was so named by Dr. Johannes Schmidt who crossed it on the 'Dana'. The direction of the Ridge is to the south-east from Socotra continued south from the Equator and then south towards the Chagos Archipelago as far perhaps as the island of Rodrigüez. The Ridge itself appears to be double. The north-eastern basin of the Indian Ocean lying between the Maldives and Laccadives on the east, the bank extending south-west from Karachi on the north, and the Chagos Archipelago on the south is about 2,400 fathoms deep, being continuous through the channel between the Chagos Archipelago and Addu Atoll, with the deep waters to the south-east. The south-western basin is about 2,700 fathoms deep to the north, and appears to be divided towards the south by a plateau less than 1,000 fathoms deep, connecting Mauritius with the Seychelles through Cargados

Carajos, Nazareth Bank and Saya de Maha Bank, and having a possible extension to the north. There appears to be a common ridge above the 1,300 fathom line on which the Maldives, Minikoi and the Laccadives are situated, Minikoi itself being part of the Laccadives, as suggested by irregularities in slope and contour, rather than of the Maldives. King Fuad Bank is probably a submerged atoll with a distinct rim about 40 feet high and a level floor 130 fathoms deep. There is a basin of water with a depth of 1,500–1,640 fathoms between the 1,000 fathom line off the mainland and the upper part of the Maldives, which does not appear to be connected with the deep waters to the south-east.

As a result of the work of No. 14 Party, Survey of India, in collaboration with the John Murray Expedition, for four weeks in March and April, 1934, Lt.-Col. E. A. Glennie reported as follows :—

'The large negative anomalies in the Maldives are remarkable; these increase towards the central meridian of the Archipelago. Precisely the opposite is the case at Minikoi, for the crustal warp anomaly is positive on land and reduces to zero at the sea station to the west, thus indicating a tectonic condition under the Laccadives apparently opposite to that under the Maldives.

From the gravity and deflection observations on the west coast of India it is known that a positive area flanks the coast as far south as Mangalore ; if this is extended to Minikoi it is significant that a line drawn from Minikoi to Mangalore will skirt the southern margin of Kalpeni and Androth Islands, Ellicalpeni Bank and other shallow soundings. It seems therefore a plausible deduction that the great positive upwarp off the Bombay coast runs south under the Laccadives to Minikoi, while the flanking depression of the crust on its east side continues out to sea south of Mangalore to the line of the Maldives, where a continental fragment of the crust has been crushed in the downwarp or submerged' (p. 96).

In his account of Addu Atoll, Sewell noted the changes that have taken place after the visits by Stanley Gardiner and Forster Cooper in 1900 and of Agassiz in 1902 with reference to the reef-platform, the outer reef, the islands of the reef-platform, the lagoon reef and the lagoon. It was not possible to ascertain definitely the relative part played by the two factors viz., the summit of the mountain on which the atoll has been formed and the varying growth rate of the reef, in determining the shape of the atoll. The north-eastern horn of the atoll is probably due to the submarine contours tending to extend to the east and north-east. There are coral heads on the south-west side of the atoll brought up by heavy waves during the south-west monsoon which has greater effect on the atoll in spite of its situation below the Equator than the north-east monsoon, which also probably accounts for the absence of coral blocks on the east side of the atoll. The islands on the west side of the reef-platform occur near its inner margin and are greater in size than the islands on its eastern side. There is also considerable difference between the east and west sides of the lagoon reef. The lagoon floor is poor in regard to coral-growth, due perhaps to the adverse effect of sulphuretted hydrogen which is comparatively abundant on the lagoon floor.

Horsburgh or Goifureehendu Atoll is markedly different from Addu Atoll, as the former is affected by both the south-west and north-east monsoons, being situated in about Lat. 4° 51′ N., Long. 72° 55′ E. On the north and north-east sides of this atoll occurs a row of islands, external to which is the outer reef-flat or boat-channel and to the inside is the lagoon reef-flat. A similar distinction into three concentric zones cannot be made out elsewhere in the atoll as the land has completely disappeared from that part of the reef owing perhaps to the action of the south-west monsoon, that blows heavily on the south and west sides of the atoll. The lagoon floor appears to be basin-shaped, not flat, being deeper in the centre (23 fathoms) than at the circumference, the floor thus sloping upwards from the lagoon centre.

[1] Regarding the reefs of the Western Indian Ocean, it has been recently pointed out that the Mascarene Region, situated farther from the Equator, differs from the Chagos Archipelago in regard to conditions of reef-growth, changes adverse to reef-growth taking place at a much faster rate than in the latter. The Chagos Archipelago seems to have remained unchanged for a comparatively long period of time after the change of sea-level resulted in the appearance of land as in coral reefs generally. With the subsequent seaward growth of the reefs on a 'talus slope' a corresponding extension of land also took place. No land is seen on the 'lagoon shoals' owing to submergence, except when Lithothamnioneæ are present on the bank assisting in the formation of a reef. Reef-forming organisms have not brought about any change in the depth or extent of the lagoon, as their growth is restricted. The banks are to be regarded as having been formed by submergence of land and not as reefs actually growing up. The Chagos Archipelago is separated from the Maldives by a depth of over 2,000 fathoms, the Archipelago itself being situated on a southward extension of the Maldive-Laccadive Ridge to 4° S., with a narrow trough probably inter-

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[1] *Vide* 'The Reefs of the Western Indian Ocean—I Chagos Archipelago; II The Mascarene Region', and 'Concluding Remarks on the distribution of the land and marine fauna, with a list of the water temperature observations', by J. Stanley Gardiner, F.R.S., in Transactions of the Linnean Society of London, Vol. XIX, Part 4, 1936.

vening between the Carlsberg Ridge and the Chagos Archipelago. Within the 1,000 fathom line the Archipelago extends from about 4° 40′ S. to 7° 45′ S., the ridge on which it is situated probably extending to farther south at a lower depth. Stanley Gardiner remarks : 'The Great Chagos Bank is the dominant feature of the group, for it is 92 miles across and 63 miles north and south within the 20-fathom line. This gives it a circumference of about 240 miles, on which there are 9 miles of surface reef, 200 miles of shoal water, 5–12 fathoms, and 32 miles in eighteen passages with over 20 fathoms, leading to a great central plateau of 38–48 fathoms with relatively few shoal banks arising upon it. The weather during our visit prevented any investigation of this bank, but the records of Great Chagos, together with the considerable information we collected verbally, do not support the idea that it is an atoll in course of formation, for much of the circumference is said to be bare of Lithothamnioneæ and large coral' (p. 396). In the Chagos Archipelago there appears to be a gradual slope down to about 50 fathoms (the depth limit for the growth of calcareous algæ and reef corals at which the water temperature suddenly drops) before the commencement of the steep, seen in most coral reefs, which is said to be of the nature of a 'talus slope' composed of detritus washed down by currents. The Chagos are situated between the counter equatorial and equatorial currents flowing east and west respectively, and their submarine topography seems to be determined by the currents set up by the tides. It appears that the 'basal platform' of the reefs and banks of the Chagos is within the 850-fathom line, the floor being comparatively smooth and clean. 'This cleanness of the floor at 500 to 800 fathoms, the nature of the "deposit" obtained from it, the absence of any thickness of deposit and the dredgings, irresistibly suggested a current-swept floor between the atolls and banks. A thin coating of "manganese" on some shells and on two pieces of rock torn off the bottom supported this idea' (p. 397). Regarding the formation of the Chagos Archipelago Stanley Gardiner suggests : 'In the Chagos we have to think either of a subsided or of a peneplaned land. The reef-building society evolved in the Cretaceous, producing its wave-resisting structures which are known as coral reefs. This gives the earliest date for the possible commencement of the Chagos coral reefs. It allows a period, perhaps of 10 million years, for a levelling-down of foundations suitable for its atolls and for a possible subsequent increased depth between them, so as to produce the present topography of the Archipelago. Such a recent planing-down may have operated upon a land that was subjected to a similar process even from Archean times.

I do not doubt the former existence of a high land beneath the Chagos Archipelago, this perhaps with mountain peaks. But I see no need to call in the help of any agencies to produce its present structure beyond the physical and chemical actions of air and water, the effects of these subsequently controlled by the bodies of living organisms ' (pp. 397-398).

Salomon Atoll seems to have been formed by a change in the sea-level, the reef growing on the seaward side. Over the greater part of the lagoon reef-forming organisms seem to have perished, partly by the deposition of mud but chiefly due to the precipitation of lime by the organisms themselves.

In his detailed account of Salomon Atoll, Stanley Gardiner says : ' The intention, when the Percy Sladen Expedition left England, was to chart an atoll in the Indian Ocean in a manner analogous to the chart of Funafuti, so that comparisons of the constructive and destructive forces at work in shaping atolls might be determined after the lapse of a period of time. Salomon Atoll was chosen for this purpose ' (p. 398). Dredging by the Percy Sladen Expedition ' proved unquestionably that the steep is the angle of accumulation of reef material formed in shallow water, the talus slope, all sedentary life upon it unimportant as building material ' (p. 412). In Egmont Atoll also there is evidence of the reefs extending on the seaward side, as in the case of Salomon Atoll, with clearer indication of a lowering of the sea-level resulting in the appearance of land. Diego Garcia with more extensive land area than in any other atoll of the Chagos Archipelago is said to be formed by ' recession of the sea ' with seaward growth of reefs all round but loss of land on the lagoon side resulting in extension of the lagoon itself. Peros Banhos, which is an abnormal atoll in several respects, is ' deemed to be in a decaying condition, perhaps in an earlier stage to that found in Great Chagos Atoll ' (p. 420) owing to loss of land being greater than the gain. The lagoon is up to 41 fathoms deep, whilst the passages, of which there are twelve, are much shallower, the maximum depth being only 15 fathoms ; this contrast in the relative depth of the lagoon and the passages connecting the lagoon with the outer sea is a unique feature. Whilst in the Southern Maldives the greater part of the lagoon floor within 10 fathoms of the greatest depth is flat, in Peros Banhos the central part of the lagoon floor is much deeper. Another unique feature is the presence of water (2–4 fathoms) over most of the lagoon shoals. Summarising his impressions, Stanley Gardiner suggests, ' that Peros Banhos is an atoll breaking up rather than in process of formation, its land, originally formed by a small recession of sea-level, gradually washing away though growing out locally, its lagoon not filling-up though its open conditions seemed highly favourable to coral growth. Can Peros represent a stage analogous to one in the history of Great Chagos Bank, still later developed in Speaker's and Pitt Banks ? ' (p. 425).

The Mascarene Region, unlike the Chagos and the Maldive Archipelago, does not possess clearly marked ' zonal structure '. In this region cementing *Lithophyllum* is comparatively absent from the seaward edge of the reefs (hence without seaward growth), coral growth less abundant, coral colonies smaller but with larger quantity of dead corals on the reefs than in the Chagos Archipelago. Stanley Gardiner held 'that the facts can only be explained on the view that the general action in progress throughout the south-west quadrant of the Indian Ocean is an erosion of all reefs on their seaward faces. This action if long continued would account for the existence of submerged banks, either by the direct truncation of former granitic, volcanic or organically formed lands' (p. 426). According to the same author, 'the chief feature of the south-west quarter of the Indian Ocean is a broad ridge included within the 1,000-fathom line that extends northwards from Mauritius to the Seychelles and probably continues south to the Amirante Bank. It does not join Madagascar, for there would seem to be three breaks of over 2,000 fathoms, viz., south of Amirante, south of Alphonse-Francois and south of Farquhar, all the islands in this region apparently rising from about this depth as isolated plateaux. Of these Providence is known to be connected with volcanic foundations. Except Seychelles (granite) and Mauritius and Réunion (volcanic) all the island rock is limestone of some coral reef facies and most of it would seem to have reached its island position by a lowering of the sea surface that was perhaps of universal occurrence.

The most peculiar structure of the region is the series of submerged banks on the Mauritius-Seychelles ridge. They are all plateaux lying within the depth zone of photo-tropic organisms, which for plants terminates at 60 fathoms or thereabouts and for animal builders, all of prime importance being dependent on symbiotic algæ, at 40 fathoms' (p. 426).

According to Stanley Gardiner the regression of coral reefs in this region cannot be accounted for by any biological reason such as sedentary organisms that cause destruction by boring into the reefs, since the activity of such organisms is decreased at the depths at which reefs of this region are situated, nor by sediment which cannot settle on the seaward sides of reefs and banks nor by precipitation of calcium carbonate for such precipitation is not visible on coral polyps on the seaward sides, nor by currents whose action is less on the sides facing the sea, nor by temperature which at 50 fathoms is not lower than 61°·9 F., nor by any decrease in the amount of plankton that serve as food material to coral polyps, for it is not liable to much quantitative variation in the Indian Ocean, nor does the chemical composition of the surface water in the Indian seas show any appreciable difference. Stanley Gardiner says, 'the only theory that fits our region is that its present coral islands, its encircling ridges and shoals, are the remains of still broader coral structures, perhaps surface structures, that were built up subsequent to the cutting down to a base level of great lands—and that the processes which produced these effects still continue in action to the present day. Such a theory fits best our phenomena, but we have no valid suggestion of any kind as to why there should be such a regression of the reefs. Topographical reasons and abundant sedimentation may help to explain the absence of reefs round Madagascar and their comparative absence off East Africa, but such an effect off the reefless Arabian coast is less clear—and the question does not arise in the Red Sea, where there are vigorous reefs along more than 1,000 miles of coasts. Ceylon on its south coast has the one slope in our ocean where the topography suggests the former existence of a barrier enclosing a lagoon, but here we have to the south the great Maldive and Chagos Archipelagoes, the reefs of which are as vigorous as those of the more equatorial waters of the Pacific' (p. 428). In short, 'the formation decay and regression of our Mascarene reefs may have been governed by world changes which may slow down and change but which never cease' (p. 429).

From his study of the insect fauna of the Seychelles, Scott was inclined to the view (with which Stanley Gardiner agreed) that the Seychelles belong more to the Oriental than to any of the other great Regions. In this connection Stanley Gardiner makes an interesting suggestion that for a further elucidation of the geographical relations of island fauna it would be advantageous to make an intensive study of the fauna (particularly insects) of the Nicobar Archipelago. The fauna of the Seychelles seems to be related more to those of Ceylon and Malaya, although several genera of primitive facies occur in the Seychelles. Stanley Gardiner says, 'a continent between India and Madagascar appeals to us much in the same way as the lost Atlantis to the newspaper public, this continent is no longer a necessity for the distributionalist' (p. 455). The island history of the Seychelles seems to have continued from early tertiary times. The fauna of the Seychelles appears to be also related to that of Mauritius and Madagascar, suggesting a former land connection between the Amirante and Mauritius. 'The topography of the submerged banks so remarkably resembles that of the Seychelles bank that our deduction that it represents former land may reasonably be applied to them, since they scarcely can be supposed to have been plateaux arising from 2,000 fms. to 50 fms. below the surface' (p. 455). In order to explain the conspicuous affinities of the Seychelles fauna and flora with those of the Oriental region Stanley Gardiner does not think it necessary to assume any former land connection. 'The time factor is large, the island was a large one and there are numerous banks which may well have been covered with land, and there may too have been a continuation southward of India where the Laccadives and Maldives now stand. The regular wind and wave currents in the region are eminently suitable to bring the plants and beasts from the Oriental region. Chagos too might have been a station on the way, but always an isolated station, because the poverty of the animals on its banks is not consistent with a former connection to the Maldives. The sea-borne organisms, finding in Seychelles a large and varied land with a multitude of new environments, would naturally react in the same way as all nature has reacted to produce evolution. Thus has been formed that fauna and flora so varied and highly specialized which is characteristic of the present Seychelles Islands. Gondwanaland, universally accepted 30 or 40 years ago, is in my opinion a doubtful proposition ; its existence depends on biological evidence and this assuredly requires no such land of tertiary date across the Indian Ocean ' (pp. 455-456).

Attention is drawn to the comparative poverty of the land fauna of the Chagos Archipelago. The results of the two Percy Sladen Trust Expeditions seem to indicate that the Chagos and the Maldives are of recent origin. The fauna of the Maldives and Laccadives is related to that of the Oriental region, and the Chagos might have derived their fauna partly from the Maldives, but mostly from the East Indies as seems probable from the systematic study of the collections made by the Percy Sladen Trust Expeditions. The latter faunistic relationship is perhaps due to larvæ from the East Indies being carried to the Indian Ocean by currents whose direction is mainly from east to west.

Stanley Gardiner regards the shallow water fauna of the Indian Ocean as having evolved from the north-west and north-east regions of that ocean, subsequently spreading towards the Pacific Ocean. In the collections made by the Percy Sladen Trust Expedition only 254 species were common to the reefs of the Chagos Archipelago and the Mascarene Region, although the total number of species recorded from the two regions was respectively 573 and 557. In these two regions as much as 55 per cent. of the organisms differed from each other, this considerable difference could be accounted for by the fact that in the Mascarene region the reefs are not clean as in the Chagos Archipelago. The former are also less protected against the action of currents. Owing to the rapid decay of the reefs in the Mascarene region the seawater contains much mud and silt which tends to become deposited on the reefs to the detriment of the fauna. On the other hand the reefs of the Chagos Archipelago are in a comparatively stable condition. The fauna of the Mascarene region might have partly migrated from the Chagos Archipelago ; part of the fauna of the Mascarenes might also have been derived from Africa. Thus according to Stanley Gardiner, the Mascarene fauna is 'made up of a combination of organisms belonging to the whole of the Indian Ocean to which is added a limited number which had made their way thus far west from the Malay region together with a larger number that have somehow spread down from the west and north. This conclusion, applied to the two sets of reef organisms, is perhaps not certain, even a little doubtful, but, if the whole Mascarene fauna to 100 fms. is considered, it becomes at once more probable, in some groups appearing almost convincing' (p. 460). The deep-sea fauna in the Chagos and Mascarene regions seems to have been derived from shallow water forms. It appears to be cosmopolitan in distribution, owing to the prevalence of more or less uniform conditions such as lack of light and currents, composition of the sea floor (largely of ooze or mud), sea-water being uniformly low in temperature but rich in oxygen, nitrates and phosphates, the food material consisting largely of organisms that sink to the bottom as they die. The comparative poverty of the deep-sea fauna in these regions is perhaps due to the hardness of the sea-floor and perhaps also to the fact that the quantity of plankton which serve as food material to the larger organisms is less in the Indian seas than in the temperate regions. In spite of the 'shallow and fierce conditions' of life on the reefs of the Chagos and the Mascarenes it is interesting to observe that the animals do not exhibit any special structural features that may be regarded as adaptations to the peculiar environmental conditions. Stanley Gardiner sums up his observations as follows :—'The conclusion I reach is that there is the deep-sea zone, little varied in the essential features of its environments, and shallower to it a distinct phototropic zone. Between the two is a special region of loose rock masses, which are loved and sought by certain animals from above and below because of their relative freedom from mud. The phototropic area I regard as one zone in a scientific sense, viz., as inhabited throughout by the same flora and fauna, always excepting some few plants and symbiotic animals that may be affected by the strength of the illumination that penetrates to them. Practically considered, however, the phototropic zone is divisible into two parts, which have their centres at perhaps 5 to 30 fms., each with its dominant plants and animals. The differences between the species of these two centres is to be regarded as due to the variations in the environments of the two depths rather than to any definite depth zonation . . . . .' (p. 463).

[1] The Madreporarian corals collected by Prof. J. Stanley Gardiner, F.R.S., in his several expeditions to the Indian Ocean, particularly of the Astræid corals, provided material, augmented by further collections from the Pacific and Atlantic Oceans and the Red Sea, for a comparative study, for the first time, of the morphological organization of their hard and soft parts, with a view to determining, if possible, the limits of species and genera, most previous taxonomic studies on corals having been based on

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[1] *Vide* 'A revision of the Recent Colonial Astræidæ possessing distinct corallites', 'Histology of the soft parts of Astræid Corals', 'Colony-formation in Astræid Corals', 'A monograph of the recent meandroid Astræidæ', by G. Matthai, 1914, 1923, 1926 and 1928.

characters taken solely from the hard parts that are liable to considerable variation. The same material, along with others, formed the basis for an exhaustive study of colony-formation in Astræid corals which was found to be by two main types of budding, intra-tentacular and extra-tentacular. In the former, different conditions were studied—distomodæal, tristomodæal, triple stomodæal, intra-mural (linear) polystomodæal, circum-mural polystomodæal and circum-oral. It was also found that directive couples of mesenteries were either present or absent in Astræid genera, irrespective of the type of budding, whether extra-tentacular or intra-tentacular. Hence the presence or absence of two directive couples of mesenteries, and therefore of biradial symmetry, assumed primary importance in classification. The presence of inter-stomodæal couples of mesenteries between neighbouring stomodæa of di-, tri-, triple, and polystomodæal conditions was a morphological feature no less significant than the presence or absence of two directive couples of mesenteries. It was ascertained that in most meandroid Astræid corals linkage of stomodæa was indirect by means of interstomodæal couples, whilst in a genus like *Symphyllia* linkage of stomodæa was direct by means of mesenterial strands. The same collection provided material for an intensive histological study of the three layers constituting the soft parts of Astræid polyps revealing the syncytial nature of the ectoderm and endoderm and the fibrous and nucleated texture of the middle lamina comparable to connective tissue and suggestive of an incipient mesodermal condition. The histological structure, no less than the gross anatomy, particularly the nematocysts—their nature, distribution and relative abundance—furnished reliable taxonomic characters. This further led to a comprehensive study of all type material of Astræid corals preserved in the European and American Museums to assist in the revision of the two groups of Astræid corals—those possessing distinct corallites and the meandroid forms.

[1] The Zoological Survey of India, since its inauguration on 1st July, 1916, has been engaged in faunistic investigation, especially of lakes and estuaries, more than morphological or economic research. The first and the most important survey was of the brackish water of the Chilka lake and its island (Barkuda). The estuarine fauna of Goa in Portuguese India was studied for comparison with similar areas in lower Bengal. A study was also made of the fauna of the Mutlah river in the Gangetic delta which was found to be poor in species but rich in individuals, and seemed to show remarkable resemblance to deep-sea fauna (particularly in regard to colouration, translucency and in the possession of filamentous processes) although the river itself has a depth of only 4 to 8 fathoms. This resemblance was

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[1] *Vide* Reports of the Zoological Survey of India, 1916–1935.

interpreted to be the result of convergent evolution brought about by certain factors common to both types of environment, such as muddy bottom and low visibility. Special attention was devoted to the study of the fauna of the Inlé Lake on the Shan Plateau. This lake, at the time of investigation, was about 14 miles long but comparatively shallow, being a 'Solution Lake' with a depth not exceeding 12 feet and muddy bottom. This lake was found to be characterized, like the Mutlah river, by abundance of individuals and paucity of species, its fish fauna being conspicuously coloured, the molluscs resembling those of deep water in several respects and also furnishing instances of variation in correlation with environment. Work was undertaken on the fauna in the environs of Calcutta, particularly of the river Hughli. A study of the geographical distribution of species was attempted along with their systematic position. A previous study of the faunas of the lake of Tiberias in Palestine, lake Biwa in Japan, the Tai-Hu in China and the Tale-Sap in Siam enabled a comparison to be made of them with the fauna of the Chilka lake. The animal societies in these different lakes seemed to show more of diversity than of resemblance.

A biological survey of the Indian freshwater molluscs and their Trematode parasites was undertaken with a view to determining the relation of the disease Bilharziasis or Schistosomiasis with any possible molluscan hosts, indigenous or otherwise, but the results were negative which showed that there was little or no risk of infection anywhere in India. In connection with this investigation a tour was undertaken to Seistan in East Persia where a study was also initiated of the aquatic fauna of the Hamun-i-Helmand which receives the river Helmand.

The aquatic and terrestrial fauna of the Punjab Salt Range was studied. An interesting investigation of cave fauna undertaken for the first time in India was that of the Siju Cave in the Garo Hills, Assam. Particular attention has been paid to the study of the fishes of hill streams in various parts of India and their structural and other adaptations to this peculiar environment. Special investigations with an economic bias have been made on behalf of Government, although in a limited sphere. An attempt was also made to study the freshwater fauna of the Andamans for a better understanding of the origin of such fauna and for comparison with the fauna of other lakes such as the Chilka lake. Attempts were also made to survey the fauna of some of the rivers of the North-west Frontier Province and of the back-waters of Cochin State. Since the Manchar lake in Sind and the back-waters of Vizagapatam were being subjected to considerable changes, the former by the establishment of the Sukhur Barrage and the latter by the construction of the harbour, a survey was made of the fauna of these changing waters. After the completion of the study of the fauna of the Chilka lake an investigation was started of the fauna (and the Hydrogen-ion concentration) of the Nerbudda river which is peculiar in flowing from east to west. A survey was made of the Burma-Chinese Frontier in the upper Shan States (to enquire into the possibility of the spread of Schistosomiasis) and of the 'relict marine fauna' of the Indawgyi lake in Burma.

Fisheries research specially on *Trochus* was conducted in the Andamans, and results of both scientific and economic interests were obtained. Survey work was also attempted in Chitral and in the Eastern Ghats, the latter in conjunction with the Bombay Natural History Society. The investigation of the fauna of the brackish streams in the Salt Range in the Punjab and of their conditions of life have been of particular value. These streams are interesting since they begin as fresh water subsequently becoming saline. Similar investigation was undertaken of the waters of the Hughli which also change from fresh to saline. The faunistic study of the Indian backwaters to the north of Calicut and Bangalore was also undertaken. Work of this kind seems to have been undertaken for the first time in India in regard to inland waters.

[1] The study of higher Zoology at a University Centre in India seems to have started for the first time at Madras more than 50 years ago under A. G. Bourne and J. R. Henderson, and a paper on 'Notes on the Anatomy of Scorpions' was published in the Quarterly Journal of Microscopical Science as early as 1889. This pioneer attempt was helped by the Provincial Government by the establishment of a Museum with an important Natural History Section, of a Marine Aquarium, a Department of Fisheries, a Marine Biological Station at Krusadai, and latterly by the University in founding a Zoological Laboratory solely for research. Numerous papers have already been published by research workers at Madras dealing with several aspects of Zoology. With the opportunities afforded by an extensive sea coast and the facilities provided by the several zoological institutions, Madras promises to become a leading centre for research in Marine Zoology. Cytology also takes a prominent place in the programme of the Research Laboratory.

It was not till twenty years later that higher zoological teaching was started in Lahore under the direction of Stephenson. Since then a band of enthusiastic research workers have contributed not a little to the advancement of zoological knowledge, several of whom are at present holding responsible research posts in different parts of the country. Particular attention has been devoted to faunistic, morphological and cytological work by the school of Zoology at Lahore. Special areas have been selected for intensive study namely Lahore (terrestrial and freshwater), Karachi (marine), and Dal Lake in Kashmir Valley. Monographs on certain groups have already been published and others are under preparation. About the same time higher zoological research was started at Allahabad under Howlett followed by Imms and Woodland. Emphasis was laid at that University on Morphology, and recently on Cytology and Helminthology. Among the older Universities Bombay started higher teaching and research work in Zoology much later than Madras, Lahore and Allahabad, but with the establishment of a chair of Zoology at the Royal Institute of Science a fresh impetus has been given to zoological work, with the result that a school of Zoology has been rapidly growing up at that University, with particular attention given to the investigation of the littoral marine fauna of the Bombay Coast. At Calcutta where considerable research work in Zoology had been carried out under the auspices of the Asiatic Society of Bengal, the Indian Museum and R.I.M.S. 'Investigator', there was no organization for higher teaching and research in Zoology at the University itself till the establishment of a zoological laboratory in 1919. Since then there has been a remarkable output of research work, especially on Morphology, Embryology, Protozoology and Entomology. Research work in Vertebrate Embryology has been a remarkable feature of the school of Zoology at the Calcutta University.

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[1] Based on information kindly supplied by the Heads of Zoology Departments in India.

Of the newer Universities Lucknow has taken the lead in zoological research work. The study of Oligochætes started by Stephenson at Lahore has been carried over to Lucknow, with emphasis laid on intensive morphological investigation especially of the excretory and blood vascular systems. The publication of several volumes of the Indian Zoological Memoirs has also been a noteworthy feature of the school of Zoology at Lucknow.

In Osmania University at Hyderabad, rightly famous for a successful experiment in imparting higher education through the medium of Urdu, the Department of Zoology has not lagged behind in contributing to the advancement of zoological knowledge. Higher zoological work at Bangalore was started at the Central College in 1911, the Department subsequently developing into the school of Zoology of the University of Mysore ; research work has been undertaken on Morphology, more particularly on Amphibia. In the recently established Nagpur University special attention has been devoted to research work in Helminthology and Entomology. In the two all-India Universities namely, Benares Hindu University and Aligarh Muslim University, facilities have been provided for advanced zoological work. In the former special attention has been devoted to research work in Cytology and Cyto-genetics. The Aligarh Muslim University, noted for its extensive and well equipped zoological laboratories, has been engaged in research work mainly on Nematodes, the Ixodidæ and certain parasitic insects.

The future of our Science in India is secure in the hands of the enthusiastic zoologists working in different parts of the country. Its advancement will be still further enhanced by the establishment of a Department of Zoology at every seat of learning in India.[1]

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[1] I am indebted to Dr. S. L. Hora for sending me in advance the following articles prepared for the Jubilee Session of the Indian Science Congress:—

'An outline of the fauna of India', by H. Srinivasa Rao.

'Outline of the progress of Zoology in India during the years 1914–1937', by H. Srinivasa Rao.

'Oceans round India', by R. B. Seymour Sewell.

SECTION OF ENTOMOLOGY

President :—M. Afzal Husain, M.A., M.Sc., F.N.I., I.A.S.

Presidential Address

ENTOMOLOGY IN INDIA: PAST, PRESENT AND FUTURE.

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I. INTRODUCTION.

It is my very pleasant duty to extend, on behalf of the Entomologists in India, a most hearty and cordial welcome to our comrades from across the seas—the Delegates of the British Association for the Advancement of Science. In the development of entomology in India, the British Scientists have played a very important part. Let us hope that their association in our deliberations this year is yet another bond that will unite us still closer for rapid advancement of entomology and service to mankind. In our efforts to learn everything about insects and, through knowledge thus obtained, to bring them under control, we are engaged in one of the greatest and noblest of all undertakings, not for the benefit of a community, or a class of people, but for all humanity.

We must be happy that after 24 years of steady growth as a branch of zoology and in the service of agriculture, medicine and veterinary, entomology has established a claim for full independence. A similar status entomology has enjoyed in International deliberations since 1910, when the First International Congress of Entomology was held at Brussels, and within the Empire entomology has been 'self-governing' since 1920, when the first Imperial Entomological Conference was held in London. Having taken birth on the auspicious occasion of the Jubilee Session of the Indian Science Congress, the future success of this new Section seems assured.

I am deeply conscious of the honour done me in inviting me to preside over the first session of the Section of Entomology and I am equally conscious of the great responsibility that rests upon me, because does not the poet say:

> 'The first brick if a mason lays untrue,
> The wall to sky if built shall rise untrue.'

I have, therefore, attempted to trace briefly the history of Entomology in India, and have ventured to offer for your consideration, some suggestions for the future development of the science to which we owe allegiance: so that the first stone be laid well and true. It is an ambitious task and I am fully conscious of its magnitude. I, therefore, crave your indulgence.

II. ENTOMOLOGY IN ANCIENT INDIA.

It is evident that man's association with insects dates back some 500,000 years, when our hoary ancestor hobbled clumsily on mother earth. His interest in insects was two-fold: they formed an occasional source of his food—spicy, crisp morsels, and 'they irritated him by day and disturbed his slumber by night'. It is certain that he must have adopted the simple method of 'hand-picking' to capture insects that formed his savoury food, and to rid himself of noxious vermin.

Coming to the period of which we have recorded history, we find the association between insects and man already well-established, mostly as bitter foes, though here and there as friends. The more ancient a civilization, the more closely interwoven this association. Hence India contests with China the claim of having domesticated the silkworm. It has been chronicled that in the year 3870 B.C. an Indian King sent as presents various silken stuffs to a Persian ruler. It must, therefore, be assumed that our forefathers were already well-versed in the manufacture of silk cloth, some 6,000 years ago (Bolle, 1917). They certainly knew how silk was spun by the silkworm, because Yajnavalkgasmati illustrates the creation of the world by God from Himself 'as the silkworm creates the cocoon from its own saliva '. Our ancient sages must have made careful observations on the life-history and propagation of this insect before they were able to place the silk industry on a sound basis.

Similarly, lac has been ' cultivated ' in India from prehistoric times. It has been in use both as a dye and as a resin for thousands of years. It is mentioned in the Mahabharata, in the Adi-Parva, that the Kauravas sought the assistance of Purochak—an architect of fame, to construct such a house as would destroy their enemy kinsmen the Pandavas. Purochak constructed a house of lac—a highly inflammable material (Misra, 1923). The Pandavas getting a timely warning, however, escaped the calamity.

References to honey-bee are very copious in ancient Sanskrit literature, honey being used as food and in rituals. It is interesting to find that the ' black-bee ' was described as a stinging insect with six legs and given the name Ṣaṭ-pada—six legged (*Amarkosa*, 1st century A.D.), hundreds of years before P. A. Latreille (1825) invented the term Hexa-poda.

There is abundant evidence to show that ancient Indians devoted considerable attention to the discovery of the medicinal properties of insects. Undoubtedly this must have entailed careful researches and extensive and elaborate observations, continued over hundreds of years. There are also abundant references in ancient books of medicine to insect tormenters of man and various remedial and preventive measures have been suggested, some of which have survived to the present day. The use of *chauri*, now a mere symbol of dignity and regalia of royalty, must have originated as a measure of warding off the attentions of flies. And, burning incenses in temples, and during religious ceremonials, to please the deities, probably had its origin as repellents against mosquitoes and similar other insects seeking refuge in the dark, cool and humid interiors of the temples. We have frequent mention in Sanskrit medical works of the repellent properties of incenses and in *Matsyapurana* an incense so potent is mentioned that where it is burnt ' no insect will be seen there, neither frogs nor snakes '.

Calamities such as insect plagues have been regarded (and are still regarded among certain people), as manifestations of Divine wrath for the chastisement of man for his misdeeds. Visitations of lice, flies and locusts mentioned in Exodus came as punishments to the Pharaohs. The consequences of sin could only be averted through repentence and prayer, and therefore the aid of the priest became necessary in insect control.[1]

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[1] Weiss (1937) has recently contributed an interesting article on ' Criminal Prosecution of Insects ' in which he has given instances of certain law suits being instituted against insect pests and supernatural aid of Church invoked for their destruction. This went on even up to the 18th century.

There are hymns in Atharva-Veda[1] concerning the control of insect pests of crops, animals and human beings. Whether these methods of exorcism, sacerdotal conjuring and cursing were considered sufficiently potent or were employed as aid to more direct methods, we cannot say.

These hymns, however, give an insight into the variety of pests that had to be destroyed, the thoroughness of destruction that was aimed at, and the revenge which was contemplated against worms, providing abundant proof of the seriousness of the situation.

In Europe the scientific study of insects has been traced back to Aristotle (384–320 B.C.). It cannot be denied that long before his time Indian learning had reached a very advanced standard, but we are ignorant of the entomological observations of the Indian contemporaries of Aristotle, Pliny (23–79 A.D.) and others. Further researches in the ancient lore of our land may bring to light many facts of entomological interest. Observations about ants and their behaviour, salvaged by Moses (1928) from folk-lore, are an earnest of what remains to be discovered. One may commend such researches, in a field as yet completely unexplored, to some entomologically minded scholars of our classics.

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[1] *Spells against worms* (from Atharva-Veda).

(1) The great mill-stone that is Indra's bruiser of every worm—with that I mash together the worm, as *khalva*-grains with a mill-stone.

(2) The seen, the unseen one have I bruised, also the *kururu* have I bruised; all the *algāṇḍus* the *çalúnas*, the worms we grind up with our spell.

(3) I smite *algāṇḍus* with a great deadly weapon; burnt, unburnt, they have become sapless, those left, not-left I draw down by my spell, that no one of the worm be left.

(4) The one along the entrails, the one in the head, likewise the worms in the ribs, the *avaskayá*, the *vyadhvará*—the worm we grind up with our spell.

(5) The worms that are in the mountains, in the woods, in the herbs, in the cattles, within the waters, that have entered ourselves—that whole generation of worm I smite.

……

……

(3) Like *Atri* I slay you, O worms, like *Kanva*, like *Jamadagni*, with the incantation of *Agastya* I mash together the worms.

(4) Slain is the King of the worms also the chief of them is slain, slain is the worm, having its mother slain, its brother slain, its sister slain.

(5) Slain are its neighbourers, slain its further neighbourers, also those that are petty as it were all those worms are slain.

(6) I crush up thy two horns, with which thou thrustest I split thy receptacle, which is thy poison holder.

III. ENTOMOLOGY IN MODERN INDIA.

TAXONOMY.

In so far as taxonomic entomology is concerned, its foundation was laid by Linnæus, and in the 10th edition of his 'Systema Naturæ' (1758), he included 12 Indian insects. During the next thirty years insect collections, made mostly by Christian Missionaries, had been sent to Europe, and Fabricius in his 'Entomologia Systematica' (1792–98) was able to include over 1,000 Indian species. Donovan's 'Natural History of Insects in India' was started in 1800. It was based on the collections of Francillon, Drury, MacLeay, Sir J. Banks and Donovan himself. Fabricius also had examined these collections. Among the collectors of the period prior to 1831 may be mentioned, among others, the names of General Hardwicke, Capt. Smee, Messrs. Saunders, Royle, and Downs. The second edition of Donovan's book, revised by Westwood was published in 1842, and Westwood's 'Cabinet of Oriental Entomology' appeared in 1847. These publications are unrivalled for the beauty of their coloured plates.

The Asiatic Society of Bengal.

The Asiatic Society of Bengal was established in 1785 and under its auspices insect collections and knowledge about insects began to accumulate. The various publications of the Society contain much valuable entomological literature. Of the efforts made to encourage scientific enquiry and to disseminate scientific knowledge, those of Lord Auckland, patron of the Society about 1836, deserve special mention. He arranged informal social gatherings for the purpose and on the 9th November, 1836, for the first time, the Governor General's Conversazione was held and 'Natural Philosophy took its place among the social recreations of the Government house'. 'A very splendid collection of insects was seen displayed on the tables and against the walls, in convenient cabinets: the newest addition to these (which comprised a portion of Dr. Pearson's and of the Asiatic Society Cabinets) was the donation of Mr. George Loch of the Civil Service to the Asiatic Society at a recent meeting' (Journal Asiatic Society of Bengal, 1936). Incidentally this shows that insect collections were being presented to the Society early in its history.

All through the 19th century taxonomic study of Indian insects received a good deal of attention and the entomological publications of that period contain a vast amount of scattered information, mostly based on the collections made in India by enthusiastic foreign amateurs, and sent to specialists in Europe for identification.

The last quarter of the 19th century is, however, of very great importance in the history of entomology in India. It was during this period that entomological work began to be actually done in the country. The Indian Museum was established in 1875, the Bombay Natural History Society in 1883, and about this time, the 'Fauna of British India' began to appear. It was during this period that Ross was making history in Medical Entomology and the foundation of Agricultural Entomology was being laid by Cotes and others.

The Indian Museum, Calcutta.

On the establishment of the Indian Museum, Calcutta in 1875, the entire collection of the Asiatic Society of Bengal was handed over to the Museum. Cotes (1896), however, informs us that, 'unlike the other portions of the Indian Museum the Entomological Section did not receive any large contingent of specimens from the Asiatic Society of Bengal', and that 'it was not until Dr. Anderson (1865–1886) was appointed Curator that any persistent attempt seems to have been made to gather together representatives of the general insect fauna of India'. Cotes tells us that previous to his appointment in 1884 the insect collection was under the care of Wood-Mason, Nevill and de Niceville, and it consisted mainly of the specimens collected by de Roepstorff from the Andaman and Nicobar islands, by Wood-Mason from Andaman and Cachar, by Peal from Assam and by Young from Kulu. Dr. Ferdinand Stoliczka had bequeathed to the Museum a considerable collection of Rhynchota. Lionel de Niceville's set of butterflies was the finest that the Museum possessed. There were some named Indian Coleoptera, in a bad state of preservation, which had been received from the Museum of the East India Company in London. There was a fine series of the Mantidæ collected and named by Wood-Mason and a few Phasmids. There was also a miscellaneous collection made by Indian collectors employed by the Museum in various parts of India.

Cotes (1896) states that in 1884 the number of specimens in the Museum was less than, 20,000. The next decade saw rapid growth and by 1894 this collection was four-times richer in specimens. At the same time it had been sorted and classified. Cotes left in 1896.

Lionel de Niceville, who had been collecting butterflies for years, was appointed to the newly created post of Entomologist to Government of India in 1901, and put in charge of the section of Entomology at the Museum. Unfortunately he died in December 1901, and after his death the post of Entomologist to Government of India was transferred from the Museum to the Agricultural Department. All Entomological work at the Museum remained practically in abeyance until 1909 when a new post of Assistant Superintendent in Entomology was created and F. H. Gravely appointed. He did valuable taxonomic work on certain families of the Coleoptera. Gravely was transferred to Madras in 1920. The post remained vacant up to 1923, when B. N. Chopra was appointed and on his transfer to another Section of the Museum, H. S. Pruthi took over charge of the Section of Entomology in 1925 and held it till 1934. He contributed to the taxonomic studies of the Jassidæ. Pruthi was appointed Imperial Entomologist to the Government of India, and his place at the Museum taken by Hafiz. Sharif, who held a temporary appointment in the Zoological Survey produced valuable work on fleas. The section has always remained a small one with just one Assistant Superintendent and a few Assistants.

From its very inception the Indian Museum, Calcutta has been a centre of systematic work on insects, and has today a collection of insects containing over 17,000 named species. This collection has been built up with the help of the Indian Museum staff, and collectors working in several parts of India, as well as by purchase of private collections and donations from amateurs. Among such amateurs was Lord Carmichael (Ex-Governor of Bengal) who donated a huge collection to the Indian Museum. Many of the staff of the Museum and of the Zoological Survey (established in July, 1916) were interested in entomology and have added to our knowledge of taxonomy.

The co-operation of entomologists in different parts of the world for working the Indian Museum collections had been obtained very early, and European and American entomologists have been closely associated all along with the development of taxonomic entomology in this country.

The Records and Memoirs of the Indian Museum contain much valuable material on insect taxonomy.

The Bombay Natural History Society.

The Bombay Natural History Society was founded in 1883. The members of this Society have done, from the very beginning, valuable work in entomology, particularly taxonomic entomology. The Society started the publication of a Journal in January, 1886. Much entomological literature has appeared in this periodical.

The Society commemorated its Golden Jubilee in 1933, and printed a very interesting and illuminating account of the entomological work done in India by its members.

Of the various groups of insects, butterflies have been most extensively collected and studied. Of the earliest writers and collectors of butterflies are Wood-Mason (1875–1881), Col. Swinhoe (1884), Moore (1884), and Watson (1890). Lionel de Niceville (1881–1902) and Marshall are the founders of systematic work on Butterflies in India. Lionel de Niceville's three volumes on Butterflies had appeared between 1882–1890, the 4th volume in manuscript was purchased by the Indian Museum and placed at the disposal of Bingham who was preparing the Fauna volumes on Rhopalocera.

Bell (1896–1910) studied the life-histories of Indian Butterflies.

Of the other workers who have contributed to our knowledge of the Indian Butterflies Doherty (1889–1891), Mackinon (1896), Mrs. Robson (1895), Leslie (1903), Young (1904), Rhe Philipe (1906–1917), Andrewes (1909–1911), Betham (1909), Hannyngton (1911), Tytler (1915), Allen (1919), Ollenbach (1919), Yates (1930), Peile (1937), and Puri (1930) have done good work.

Sir George Hampson's (1888–1910) name is familiar to all students of Indian Heterocera as the author of the four volumes on Moths in the Fauna of British India. Dudgeon (1895–1906) has also described many Indian Moths. Fellows-Mansion has done good work on Sphingidæ, while Prout (1928) has published much on Geometridæ.

Meyrick's (1908–1913) work on Microlepidoptera is of outstanding merit. Fletcher's studies on the life-histories of Indian Microlepidoptera are valuable additions to our knowledge of the group.

Of the early writers on Indian Coleoptera the name of Baly (1886) stands out prominently. Little work on Indian Coleoptera appears to have been done up to 1910, when Maulik published his admirable work on Chrysomelidæ. Gravely (1913–1923) has done good work on Tenebrionidæ and Passalidæ. Gardner has done pioneer work on the systematics of the larvæ of Coleoptera. The list of present day workers on Indian Coleoptera include such familiar names as Arrow, Andrewes, Blair, Marshall and Ochs.

The first worker on Indian Hymenoptera is Wood-Mason (1875–1881). He was followed by Forel (1885–1902) who has done excellent work on Indian Formicidæ. The best work on Hymenoptera, however, is by Bingham (1888–1908) whose collections form the basis of his Fauna volumes on the Order. Nurse (1903–1914) who collected in Baluchistan and Simla also made valuable contributions to this order. Lately he presented his collections of 10,000 Hymenoptera to the British Museum.

Other workers on the group are Cameron, Turner, Hingston, Mani, Wroughton, Rama Krishna Ayyar and Uani. Mukerji, Negi, Misra and Gupta have studied the ants and the three latter in relation to the lac insect.

Giles in 1900 contributed a paper on Mosquitoes and Malaria to the Journal of the Bombay Natural History Society. This was followed by descriptions of some new species of mosquitoes by Cogill. It was, however, Theobald who wrote regularly on Indian Culicidæ between 1906–1910. Recently Barraud and Christophers have written Fauna volumes on Indian Culicidæ. Other workers who have contributed to our knowledge of Malaria and Mosquito are Liston, Bentley and Covell. Russell has published a series of useful papers on Parasitic Diptera. Sinton has worked on the sandflies and Mitra on Culicoides. Brunetti (1907) wrote a number of papers on Diptera and published the Fauna volumes on the group. Important contributions to our knowledge of Diptera have also been made by Keiffer (1909), Bezzi (1913), Cross (1926), Edward (1932), Isaac, Bhatia and Puri.

Aitken (1884–1889) and Kirkaldy and Kershaw (1909) are the earliest writers on Indian *Rhynchota.* They were followed by Distant who wrote the Fauna volumes on Hemiptera. Green (1899) studied Coccidæ—a group of great economic importance and his 'Coccidæ of Ceylon' contains material of much value to Indian students. Karagode, Rama Krishna Ayyar, and Mahdi Hassan have also made valuable contributions to this family. Pruthi has studied Jassidæ. Das (1915) worked on the Aphididæ of Lahore, while Krishna Murti is studying the Aphididæ of Mysore. Crawford (1912) has done work on Psyllidæ and Maskell, Peal, and Lamba on Aleurodidæ.

Liston (1904) studied fleas in relation to plague. Gragg and Sharif have made systematic study of Siphonaptera.

Laidlaw (1911) started the study of Odonata and Fraser made an intensive study of Indian Dragonflies, his three Fauna volumes providing a splendid study of the order.

Wasman wrote on the Termites in 1889. Assmuth took up this work but did not complete it. His collection was later described by Holmgren. Later on Fletcher also made contributions to this very important group. Dr. Anandale also interested himself in Termite Mounds.

Wood-Mason (1875–1881) laid the foundation of the study of the order Orthoptera by his work on Phasmidæ and Mantidæ. Cotes studied the locust, *Acridium peregrinum* in 1899. Of recent workers on the order names of Giglio Tos (1914), Chopard (1911) and Uvarov deserve special mention.

Bagnall (1912) and Rama Krishna Ayyar have studied Thysanoptera.

Our knowledge of Dermaptera we owe to Burr, of Trichoptera to Dover and Uartynow, of Neuroptera to Needham, of Thysanura to Silvestri and of Collembola to Carpenter.

Number of species of insects known from India.

Blanford in 1881 put down the number of species of insects known from this country at 12,100; Lefroy (1909) attempted a similar census 28 years later and raised the figure to 29,700; in 1917 Fletcher put it at 35,000. On the basis of the information contained in the ‘ Lists of publications on Indian Entomology ’ (1920–1934), it is estimated that over 5,000 new species have been described since 1917. It will, therefore, be safe to estimate that by now the species of Indian insects known number 40,000.

As to the number of insect species actually existing in India there has been a gradual rise in estimates. Cotes estimated twenty thousand to be a moderate computation, Fletcher (1919) raised this figure to 70,000. Sharp (1919) stated—‘ that no more than one-fourth of the insects existing in India are represented in any collection or even in all the collections if they could be united and brought together in one ’.

The number of the existing species of the insects of the world has been variously estimated at 2·5 millions to 10 millions and the latter figure is certainly nearer the truth. India's share of the variety of insect forms cannot be less than 25 per cent. of the world's and that will bring the figure to 2·5 millions. On this basis, of the insects of our country we know only one for every sixty we know not. If the estimates of Blanford, Lefroy and Fletcher were correct then during 1881–1917 additions to the number of the species described were being made at the rate of 640 per annum, while during the last twenty years it has been about 250 per year.

Our Insect Collections.

Although we may claim that insect collecting in this country has gone on continuously for over a century and a quarter, yet the condition of our collections is unfortunately distressing. Our main general collections are at the Imperial Agricultural Research Institute, New Delhi, the Indian Museum, Calcutta, and the Forest Research Institute, Dehra Dun. There are also the collections of the Bombay Natural History Society and those of the various Medical Institutes, provincial Agricultural Colleges, some provincial Museums, local societies and some of the Universities.

Through the courtesy of the officers in-charge, I have obtained figures regarding the present condition of the three of the first named collections (see statement below). From the information available it is estimated that the number of known species in all the collections in India does not exceed 25,000. This number is 10,000 short of Fletcher's estimate of 1917 and 15,000 short of the computation now made.

Taking a few specific instances we find the position very disappointing. Distant (1902–1918) described 4,005 species of the Rhynchota (he did not deal with the Psyllidæ, Aphididæ, Aleurodiadæ and Coccidæ), but in all the main collections in India we have not more than 1,600 species represented. Thus, of the Rhynchota of our own country, all our collections put together, do not contain more than 33 per cent. of the species

Approximate number of species of Insects in different collections in India.

	Imper. Agri. Res. Inst., New Delhi.	Ind. Museum, Calcutta.	Forest Res. Inst., Dehra Dun.	Estimated number in all collections in India.
Hymenoptera ..	1,000	1,397	600	1,450
Diptera ..	2,500	3,236	400	3,500
Lepidoptera ..	8,000	6,068	3,300	8,750
Trichoptera ..	....	140	....	....
Coleoptera ..	5,000	3,617	7,000	7,500
Rhynchota ..	1,500	1,575	1,000	1,600
Neuroptera (Sensu-antiquo) ..	....	162	250	260
Orthoptera (Sensu-antiquo) ..	1,500	1,193	300	1,700
			TOTAL ..	24,760

Types of Indian Insects.

	No. of spp. described.	Types in India.		Types outside India.		Types unaccounted for.	Remarks.
		Indian Museum.	Pusa Collection.	British Museum.	Other foreign museums.		
FAUNA OF BRITISH INDIA.							
1. *Coleoptera.*							
(i) Chrysomelidæ (Maulik) 1919, 1926, 1936 (3 volumes) ..	1,157	24	1	675	364	111	
(ii) Lamellicornia (Arrow) 1910, 1917, 1931 (3 volumes) ..	1,041	9	..	446	477	109	
(iii) Carabidæ (Andrews) 1929, 1935 (2 volumes) ..	494	17		177	283	17	
2. *Hymenoptera* (Bingham) 1897, 1913, Vols. I, III. ..	1,405	17	19	139	254	976	
3. *Odonata.* (Fraser) 1933, 1934, 1936 (3 volumes) ..	536	37	1	117	292	81	For. Res. Inst. D. Dun, 3. Darjeeling, 5.

which were known from India by 1918. Let us take another instance. Fraser (1933–1936) deals with 536 species of the order Odonata in his three volumes of the Fauna of British India, and we have no more than 260 species represented in all the collections of our country, and of the types we have but 46.

It is only comparatively recently that work on Odonata was started. Of the Chrysomelidæ, Lamellicornia and Carabidæ, 2,692 species have been described in eight volumes of the Fauna of British India (1910–1936) and of these we have only 51 types in India. Of 1,982 species of the Hymenoptera included by Bingham, in his two volumes of the Fauna (1897–1913) we have only 36 types in our collections. (See statement above.)

For comparison let us study the figures for North America (Hinds, 1934). In 1932, the number of insect specimens at the National Museum of Washington was 4 million and there were 170,000 named species and 50,000 types. The Canadian Museum at Ottawa had 800,000 specimens, including 30,000 named species and 4,000 types.

The slow pace at which taxonomic work has gone on in India may be judged from the following specific instance. The Aleurodidæ are of considerable importance as pests of crops and fruit trees. Maskell, the first to study Indian Aleurodidæ, described 5 new species in 1895. Peal, 8 years later (1903) added 7 more species from India. About that time rapid progress was being made in America and Quaintance had, by 1909, listed some 160 species, and since then many more have been added. In India it was not till 1931 that Lamba made a study of this family and recorded 44 species (not including 17 already described) of which 25 were new to science. Lamba's work was based on the material collected mainly from the Pusa Estate—an area of a few square miles. An investigation carried out over the entire country will show that perhaps ten times as many more species still remain undescribed as have been described so far.

Of course there are some groups which have received greater attention than others. Mosquitoes for instance, because of their medical importance, have been collected and studied very intensively. Till about 1890 only four species of mosquitoes were known from India, but by 1917 over 200 species had been described (Fletcher, 1917), and within less than 20 years Christophers (1933), and Barraud (1934) described 315 species of Culicidæ in the Fauna of British India. Again, while in 1889 Cotes and Swinhoe catalogued 225 species of the Microlepidoptera, by 1917, i.e. within less than thirty years, well over 2,000 species had been described from India (Fletcher, 1917). These instances show what amount of work remains to be done in every group of the class Insecta.

PUBLICATIONS ON SYSTEMATIC ENTOMOLOGY.

The Fauna of British India.

Hampson's four volumes of the Fauna of British India on Heterocera (1892–1896), followed by a volume on wasps and bees (1897) by Bingham appeared during the last decade of the 19th century. The remaining 38 volumes, so far published, came out during the twentieth century, and as many as eleven volumes during the last seven years. Some of the early volumes are already out of date. A large number of orders has not yet been touched at all.

India owes a deep debt of gratitude to those British entomologists who have contributed towards this valuable record of Indian Insects. Lately, it is gratifying to note, some Indian entomologists have come forward to take their share in this national work. Maulik's volumes on Chrysomelid beetles have maintained the high standard of the series, and we are glad to see it announced that Sharif has been selected for the task of preparing volumes on fleas, lice and ticks. Let us hope that more and more of this work will be entrusted to indigenous talent, and more and more of our young entomologists will qualify to take such work in hand.

Catalogues of Indian Insects.

An insect catalogue is the dictionary of an entomologist and also his directory. At present in most cases we do not know what we possess and where it is ? Without catalogues no taxonomic work is possible. Cotes when attempting to arrange the collection of moths in the Indian Museum felt the need of a catalogue. He commenced this laborious task and Col. Charles Swinhoe, who had amassed through his long service in many parts of India, one of the largest of amateur collections of Indian moths in existence, came to his help. After three years of hard labour the catalogue of moths was completed, and the Museum specimens arranged. Similarly, the work of arranging at the Indian Museum collections of different groups was taken up side by side with the work of cataloguing. Catalogue of Rhynchota by Aitkinson is one of the earliest attempts.

Catalogues, check lists, and similar other publications have appeared from time to time in the publications of the Asiatic Society of Bengal, the Indian Museum and the Zoological Survey, the Journal of the Bombay Natural History Society, the Indian Journal of Medical Research and various publications of the Imperial Department of Agriculture, and other periodicals but the credit of making a most organized attempt to publish a series of the Catalogues of Indian Insects goes to Fletcher. He placed this matter before the 3rd Meeting of the Entomologists in 1919, and his proposal received unanimous support. Government sanctioned expenditure on these publications and the entomologists came forward to help. The first part of the Catalogue of Indian Insects was published in 1921. So far 23 parts have appeared and a few more parts are ready for publication. Of these Fletcher himself was responsible for 6 parts. However, up to date, not more than 25 families have been dealt with, the total number of families recognized by Fletcher (1926) being 495. This just shows how far we have lagged behind in this work, and what tremendous concerted and co-operative efforts we must make in this direction.

In the past much valuable taxonomic work has been done by amateurs, staff of the Indian Museum (now Zoological Survey of India), medical entomologists and the entomologists in the Agriculture and Forest Departments.

Pure Entomology—other aspects.

Exceedingly little work has been done in India on other aspects of pure entomology in general. It is only recently that the teachers at the Universities and their post-graduate students have selected entomological subjects for research. Mukerji and his pupils from Calcutta, George and his pupils from Bombay, Misra and his students from Benares, students of the Zoology Schools of Lahore, Lucknow and Aligarh have made valuable contributions. Vishva Nath from Lahore, Asana from Gujarat (Sind) and Bhattacharya from Allahabad have selected insects for their cytological work.

APPLIED ENTOMOLOGY.

Agricultural Entomology.

Indian Museum, Calcutta.

The first Institution that undertook applied work side by side with taxonomic work, was the Indian Museum, and till the close of the 19th century the Museum continued to be the centre of all research and information on Indian insect pests. Wood-Mason (1884-85) carried out investigations on the *Tea bug* and *Tea mite* of Assam on *Paraponyx oryzalis*—a pest of rice in Burma. He answered enquiries about noxious insects and their control, addressed to him from all over the country. In 1888 Cotes undertook investigation on the wheat and rice weevils of India, and soon after the Trustees of the Indian Museum officially took upon themselves the responsibility of investigations on crop pests of India as a part of the work of the entomological section of the Museum. Circular letters inviting co-operation of officials and others resulted in the accumulation of a large quantity of material and information, particularly from the Provincial Departments of Land Records and Agriculture.

Cotes published the results of his investigations on applied entomology in the first three volumes (1884–1896) of the Indian Museum Notes—a publication specially started for the purpose. Cotes left the Museum in 1896 and the subsequent two volumes (1900, 1903) of the Indian Museum notes were compiled by Barlow (who died in 1900) and Peal.

Rapid increase in Entomological work and demand for a proper study of crop pests necessitated the creation of the post of Entomologist to Government of India. In January, 1901, as has been stated above, Lionel de Niceville was appointed to this post with headquarters at the Indian Museum. He was required to make observations on the crop pests in the field and in actual areas of their occurrence. He visited Darjeeling to study the Mosquito Blight of Tea, contracted fever and died of it in December, 1901. E. P. Stebbing officiated as Superintendent of the Indian Museum for sometime during 1903 and he published Part I of the sixth volume of the Indian Museum Notes. This was the last publication on Economic Entomology from the Indian Museum.

Imperial Agricultural Research Institute, Pusa.

H. Maxwell Lefroy succeeded de Niceville as Entomologist to Government of India in 1903 and was stationed at Surat for the study of cotton pests. In 1905, when Lord Curzon reorganized the Department of Agriculture, a Central Agricultural Research Institute was started at Pusa and Lefroy transferred there as Imperial Entomologist to the Government of India. Lefroy came to India as a young man, ‘ insistent and forceful ’, full of enthusiasm and energy. He set out to build a collection, studied the life-histories of insects, and devised control measures against insect pests. The progress made by him and his co-workers was indeed phenomenal. Three years after his arrival in India Lefroy published his most useful book ‘ Indian Insect Pests ’ (1906), and after another three years his classical work on Indian Entomology ‘ Indian Insect Life ’ (1909), [unfortunately now out of print], covering 786 pages, containing 536 diagrams and 84 beautiful coloured plates. This book is a monument to the knowledge, energy and industry of Lefroy and his co-workers of that period.[1] In 1912, Lefroy left India, though fortunately he was not lost to Indian Entomology. At the Imperial College of Science and Technology he trained a number of Indian Entomologists and his deep interest in India and her Entomological problems continued. He visited India again in 1915-16 and wrote a comprehensive report on Sericulture. Those who have had the privilege of working in his laboratory at the Imperial

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[1] Misra, Ghosh, Dutt, Naoroji.

College of Science would remember his contagious enthusium for entomology. Lefroy was associated in his work by Howlett, a man of brilliant intellect and charming personality, an original thinker and an excellent artist. Howlett joined as Second Imperial Entomologist in 1907 (in 1912 the designation of the post was altered to that of Imperial Pathological Entomologist). Howlett died in August, 1920.

T. Bainbriggs Fletcher joined in April, 1910 as Supernumerary Entomologist and was transferred to Madras as Entomologist to Government in April, 1912. He returned to Pusa in December, 1913 as Imperial Entomologist and held that post till 1932. During his time insect taxonomy received the greatest attention at Pusa and he built up a splendid library and a valuable collection particularly of the order Lepidoptera.

C. W. Mason (1912) joined as Supernumerary Entomologist and during his short term of service he did valuable work on the birds of Pusa. (Mem. Dept. Agric. India, No. 3.)

Howlett's place was taken by Isaac in June, 1922 as Second Entomologist (Dipterist).

Fletcher (1917) submitted to the Indian Industrial Commission of 1916–18 an elaborate scheme to set up a Central Organization for all pure and applied work including medical, veterinary, agricultural and forest entomology, in India. This Bureau was to consist of 20 expert entomologists, 23 Entomological Assistants with necessary staff. The non-recurring expenditure on building, etc. was estimated at about Rs.14,00,000 and the annual recurring expenditure at Rs.4,41,900. The Industrial Commission gave their support to the scheme, but because of the changes in the organization of the administration of the country, by which Agriculture, Medicine and Veterinary became transferred subjects under the Provincial governments, and partly because of the magnitude of the scheme, it did not receive consideration from Government.

Fletcher's place as Imperial Entomologist was taken by Hem Singh Pruthi in 1934.

During the last 30 years or so several thousands of Indian insects have been reared in the Insectary of the Imperial Agricultural Research Institute at Pusa and illustrations, mostly coloured, of their life stages made. Several monographs on the life-histories of the more important groups—for example, Microlepidoptera, Hymenoptera, Coleoptera, Diptera, etc. have been published. Considerable amount of research work on several serious pests of Indian crops has been conducted. Bollworms of cotton, Borers and Hoppers of sugarcane, pests of fruits, etc. etc. have been studied. Investigations on Termites, stored grain pests and insectivorous birds have also been undertaken. The results of these investigations have appeared as Memoirs of the Department of Agriculture in India and Bulletins of Agricultural Research Institute, Pusa.

Agricultural Entomology in the Provinces.[1]

It was in 1905 that Mr. Sly in his proposals for the development of Agriculture provided for a qualified Entomologist in each province. The Secretary of State for India, however, negatived this proposal. In 1909 there were only 13 Entomological Assistants in the provinces, by 1910 this number had increased to 16—5 for teaching and 11 for field work. It was not till 1912 that a Government Entomologist was appointed in Madras, the Punjab followed in 1919 and the U.P. in 1922. In these three provinces Entomological work developed and expanded. A class II Officer was appointed in Nagpur in 1931 but the section is yet a one man show. Bombay, Bengal, Bihar, Orissa, Assam, Sindh, North-West Frontier Provinces, and Baluchistan still continue to have a very small staff of Assistants for pest control.

In Madras the Entomological work was started in 1902-03 with one Upper Subordinate who worked under the Economic Botanist. This arrangement continued till 1908-09 and by then the number of Upper Subordinates had increased to three. In April, 1912 Bainbrigge Fletcher was appointed Government Entomologist, Madras. Fletcher was transferred to Pusa in December, 1913 and E. Ballard appointed Government Entomologist in January, 1914. On Ballard's retirement, Rama Chandra Rao was appointed Entomologist to Government, Madras, and held this post till December, 1930, when he took over as Deputy Locust Research Entomologist in the Locust Research Scheme of the Imperial Council of Agricultural Research. He was succeeded by Rama Krishna Ayyar, who retired in July, 1935. This veteran entomologist continues to take keen interest in entomology. Cherian is now officiating as Entomologist.

In 1914 Fletcher published his book on 'Some South Indian Insects' and brought together all the available information on South Indian insects and other crop pests, with useful chapters on applied entomology.

Entomological work was started in the U.P. as early as 1906 with the appointment of one Assistant, placed under a Deputy Director of Agriculture. A regular Entomological Section was created in 1921 and P. B. Richard appointed Entomologist to Government. The main problem of the Entomological Section has been the control of Pink Bollworm. For this investigation the Indian Central Cotton Committee gave, during the years 1922 to 1934, a grant of Rs.1,46,731.

The Entomological Section in the Punjab came into existence in 1905, and was placed under the Government Economic Botanist, Lyallpur. An Assistant Professor of Entomology was appointed in 1908 but it was in 1913 that the Section became independent under Madan Mohan Lal. Till 1919 the staff consisted of one Assistant Professor of Entomology and three Agricultural Assistants. In September, 1919 M. Afzal Husain was appointed Entomologist to Government, Punjab. Since 1919 the Entomological Section has grown steadily and at present the staff consists of the Government Entomologist, one Assistant Entomologist, two Assistant Professors, two Research officers (one on Cotton Research Scheme financed by the Indian Central Cotton Committee) and 34 Research Assistants.

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[1] Based on the information kindly supplied by workers in the provinces.

Perhaps Baluchistan was the first province where applied entomology received attention. James Cleghorn in 1890 contributed an interesting article on the melon fruit fly of Baluchistan —*Carpomyia pardalina* Bigot. The Government of Baluchistan invited Stebbing to study the borers affecting the shade and fruit trees in Quetta. In 1914 the Imperial Department of Agriculture established a Fruit Experimental Station at Quetta. However, it was not till 1932 that the Agricultural Department was organized in Baluchistan and a small Entomological staff sanctioned.

Entomological work in Indian States.

Of the Indian States, Mysore was the first to employ an Entomologist. In fact Coleman was appointed Entomologist and Mycologist in 1908 before Entomologists had been appointed in any of the provinces of British India. When Coleman was appointed Director of Agriculture, K. Kunhi Kannan, who had been associated with Coleman in his work, was appointed Entomologist and was given a staff of three Assistants. The Entomological Section of Mysore continues to maintain its tradition of useful work.

Kashmir, well known for its apples and pears, is the best locality in India for hilly fruits. Till as late as 1913 no attention was paid to insect pests of Agricultural and Horticultural importance. During this year, Ram Gopal, the then Director of Agriculture and Horticulture, discovered San Jose' Scale playing havoc with fruit. By 1921 this pest and the Woolly Aphis had been definitely identified. In 1923 the State obtained the services of Fletcher who studied the San Jose' Scale. It was in 1930 that a small Entomological Section was inaugurated.

Lately investigations have been started in Hyderabad-Deccan on the Pink Bollworm of Cotton, financed by the Indian Central Cotton Committee.

Work done in the Provinces and States.

Although some systematic work on Curculionidæ, Coccinellidæ, Parasitic Hymenoptera, Thysanoptera, Syrphidæ, and

Coccidæ has been done in Madras, the Provinces and the States have been mainly devoting their attention to the study of insect pests. Of the insect pests the following have received special attention :—*Hieroglyphus banian* Fb., *Colemania sphenaroides* Boliv., *Hispa armigera* Oliv. *Pempheres affinis* Fet., *Aulacophora abdominalis* F., *Trogoderma khapra* Arr., *Calandra oryzæ,* Linn ; *Schœnobius bipunctifer* Wlk ; *Spodoptera mauritia* Basl, *Phothorimæ opercullela,* Zell, *Earias* spp., *Platyedragoss ypiella.* Saund., *Scirphophaga nivella* Fb. *Argyria sticticraspis,* Hampsn. *Pachydiplosis oryzæ ; Chætodacus zenatus* F., *Carpomyia vesuviana.* Bigot., Termites ; *Leptocorisa varicornis.* F., *Pyrilla* spp., *Idiocerus* spp. *Diaphorina citri* Kuw., *Aleurodidæ ; Eriosoma lanigerum* Haus. and other Aphididæ, *Aspidodiotus perniciosus* Comst. and other Coccidæ ; and *Thrips tabacci,* Lind. In addition, these Provinces and States have also been organizing control measures against pests. Recently the Punjab has started (with a special staff of three Assistants, the strength to be increased to 6 next year) a Plant Protection Service for undertaking large scale control operations, thus separating the Research and the Field staff.

The Biological control of insects has also been receiving attention. While the Punjab and Madras have studied the parasites of *Bephantis serinopa* and *Earias* spp. respectively, Mysore has been carrying out mass production of *Trichogramma.*

The Punjab has also done considerable amount of work on the feeding habits of birds.

Further, such useful industries as sericulture, lac culture and apiculture have been receiving their due share of attention from the Imperial Institute of Agricultural Research, Provincial and State Entomologists. In all cases efforts have been and are being made to encourage these cottage industries.

Indian Central Cotton Committee and Entomological Research.

The Indian Central Cotton Committee was established in 1921 and since then many research schemes dealing with insect pests of cotton have been financed by this body. Particular mention may be made of the Pink Bollworm investigations in the Punjab and the United Provinces, the Spotted Bollworm investigations in Surat and the Punjab, the White-fly investigations in the Punjab, the *Pempheres* investigations in Madras and the Jassid investigations in the Punjab. The Indian Central Cotton Committee has so far spent over Rs.10,30,000 on Entomological Research and control of cotton pests.

In the training of Indian Entomologists the Indian Central Cotton Committee has played a very important part. Since 1922, 11 post-graduate scholars have received training in India and abroad at an approximate cost of Rs.50,000 to the Committee.

Imperial Council of Agricultural Research and Entomological Research.

The Imperial Council of Agricultural Research was set up in 1929, to initiate and co-ordinate Agricultural Research on an all-India basis. It has financed various schemes of Agricultural interest costing over 85 lakhs of rupees, of which the entomological schemes had a share of Rs.7,60,450.

The very first problem which the Council took up was that of the Desert Locust—an ancient scourge of many lands. The Locust Research Scheme was started in 1930. M. Afzal Husain was in charge of the scheme as Locust Research Entomologist for 1930–1933, and was succeeded by Rama Chandra Rao in April, 1933. A portion of the staff worked on the life-history and bionomics of the Desert Locust at Lyallpur and the rest formed survey parties to determine the breeding grounds of the pest in Baluchistan, Sind and Rajputana, with headquarters at Quetta. In 1933 the scheme was divided into two parts. The headquarters of the survey portion were shifted to Karachi while the bionomics and phase problems were continued to be studied at Lyallpur. The Council has already spent about 5 lakhs of rupees on this scheme and as Sir John Russell has remarked, the results achieved are of outstanding value. A number of papers have been published. As a result of this investigation much valuable knowledge has been gained and it is certain that locust cannot be upon us without a warning, and besides, with the knowledge we possess today, warfare against this pest will be brought to a successful termination, speedily and economically.

The other important investigation under the aegis of the Imperial Council is that on the Sugarcane pests. A sum of 96 thousand rupees has been allotted for this work which is being conducted by Issac at New Delhi, with sub-stations at Karnal, Pusa and Coimbatore. Parasites of these pests are being collected with a view to investigate the possibilities of biological control.

The San Jose' Scale, an introduced pest, has spread in the submontaneous tracts of the Punjab and N.W.F.P. and has established itself in Kashmir and other fruit growing localities. The Council have initiated, under Khan A. Rahman, a survey to ascertain the distribution and incidence of San Jose' Scale and other fruit pests. A survey of Codling-moth in Baluchistan has just been concluded by the Imperial Entomologist (Hem Singh Pruthi). A scheme to determine insecticidal value of plant fish-poisons was sanctioned in 1935 at a cost of Rs.15,288 at Bangalore. A scheme for the investigation of *Pachydiplosis oryzæ* has been financed, at Nagpur.

In addition to these exclusively entomological investigations, insect-life is being studied in several of the other schemes run by the Imperial Council. The Fruit Research scheme at Chaubattia (U.P.) has an entomologist making a tree to tree survey to determine the incidence of pests and to correlate this with soil conditions. Entomological workers are associated with sugarcane investigations in various provinces.

Indian Tea Association.[1]

Tea has always suffered from ravages of various insect pests to which Mann drew attention in 1903. It was not, however, until 1905 that an Entomological Laboratory was established at Kannykorrie (Assam) in charge of C. B. Antram. In 1911 Antram resigned and E. A. Andrewes succeeded him. Entomological work was transferred to Tocklai in 1913. Life-history of important pests of tea and their control measures have received attention. Andrewes made a very exhaustive study of *Helopeltis theivora*—'Tea Mosquito'. On account of financial world-depression the Entomological staff was reduced and Andrewes resigned his appointment in 1932. Similarly the United Planters Association of Southern India, in their Tea Scientific Department which was organized about 12 years back, undertook work on insect pests. It was about 1932 that they appointed an Entomologist. Besides *H. Theivora* the following pests of tea have received attention:—red spider *Tetranychus bioculatus*, Limacodid grubs, which have come into prominence lately, *Homona coffearia*, *Xyleborus fornicabis*, termites, *Toxoptera amantii* and a few others.

Lac Association.

Researches on lac were conducted at Pusa by C. S. Misra, and at Dehra Dun by A. D. Imms and N. C. Chatterjee; and A. B. Misra shared his father's enthusiasm and also did valuable researches on the lac insect.

The Government of India appointed a Commission in 1921 to report on the condition of lac cultivation and as a result of their recommendation established in 1925 the Indian Lac Research Institute at Ranchi with (Mrs.) Dorothy Norris as the first Director. On her retirement Sen was appointed Director.

The Institution is engaged in finding out the improved methods of cultivation as well as industrial uses of lac and shellac. Predators and parasites of the lac insect are also receiving attention. Glover, Gupta, Misra and Negi have done valuable work. Work has also been done in some other parts of India.

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[1] Information kindly supplied by Carpenter and Anand Rao (Entomologist).

Forest Entomology.[1]

Simultaneously with the development of Agricultural Entomology, the insects attacking forest trees were receiving attention, and there are numerous references to forest insects in the Indian Museum Notes. In 1898 E. P. Stebbing published a booklet on Forest Insects. He was appointed Imperial Forest Entomologist in 1900, and when the Imperial Forest Research Institute was established at Dehra Dun in 1906, Stebbing was appointed Forest Zoologist. He was able to make an extensive survey of Forest Insects, chiefly of the Insect Fauna of *Shorea robusta* and the conifers. In 1909 he left India. In 1914 appeared his excellent book on 'Indian Forest Insects'.

Imms was appointed Forest Zoologist in 1911 and, within his short term of office of 16 months, he did valuable research work and laid the foundation of an authentically identified insect collection, a good library, and an adequate laboratory equipment, the three essential requirements for research. C. F. C. Beeson was appointed Forest Zoologist in 1913 (the designation of this post was later changed to Forest Entomologist). During Beeson's term forest entomology made good progress. and a systematist was added to the staff. M. Cameron was appointed Systematic Entomologist in 1920 and was succeeded in 1923 by J. C. M. Gardner. Many insect pests of Forest trees have been studied and control measures devised. Ecological standpoint has received particular attention. *Hoplocerambyx spinicornis* Newm. the heartwood borer of *Shorea robusta* has been controlled by an ingenious device of trap-trees felled at the time of the flight period of the beetles. Biological control of defoliators of teak, 'Shisham' (*Dalbergia sissoo*), and mulberry has been taken up as a special line of investigation. An intensive survey of the fauna of sandal tree was undertaken in connection with the Spike disease (Beeson, Chatterjee and others).

Considerable advances have been made in systematic entomology, and a reference collection of 15,657 species has been built up, and further additions are being made every year. Gardner has paid particular attention to the classification of the coleopterous larvæ, and similar work on the lepidopterous larvæ is in progress. The results of these investigations have appeared in the Indian Forest Records, of which a separate Entomological series has been started lately.

Medical Entomology.

Medical Entomology provides the most dramatic and glorious chapter in the history of applied entomology. It is only forty years ago that insects were first incriminated as agents in disseminating human and animal diseases and since then discovery has followed discovery in rapid succession, and the results of these discoveries have been of utmost importance to humanity.

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[1] Based on the information kindly supplied by Gardner.

India has made valuable contributions. Ronald Ross, in 1898 discovered the developmental stages of the bird-malaria in the gut of a culicine mosquito, and announced to the world his discovery that certain ' dapple-winged mosquitoes ' were the carriers of malaria. Immediately a Commission to investigate the malaria problem was appointed. Daniel, one of the members of this Commission, arrived in India in December, 1898 to substantiate the findings of Ross. By 1900 the Anopheline mosquitoes as vectors of human malaria had been conclusively implicated and had already attracted the attention of Austin, Giles, James and Liston. Giles advocated the desirability of a thorough investigation on the Indian Culicidæ and invited workers to send him specimens.

Partly through the discoveries of Ross, and the group of eminent workers that followed him, and partly because of the importance of malaria to India, the largest amount of entomological work has been done on mosquitoes. Theobald had obtained, in 1900, collections of biting insects of India and described the mosquitoes in his ' Culicidæ of the World ', the first volume of which was published in 1901. Stephens and Christophers, member of the Malaria Commission arrived in 1901 and started their Entomological investigations. In 1904 James and Liston wrote their classical work giving descriptions of the species of *Anopheles*. In 1905 Christophers wrote a Memoir on the Importance of Larval Characters in the Classification of Mosquitoes. The Imperial Malaria Conference, at its first meeting, held in 1909 recommended the creation of a Central Scientific Committee to carry out routine work on the distribution and bionomics of the different species of *Anopheles*. In 1910 the Central Malaria Bureau was started and field laboratories were added to carry out research work on mosquitoes and malaria.

At this period (1911) an important step was taken which greatly helped the development of medical entomology in India, viz., the Indian Research Fund Association was organized to supervise and finance research enquiries into various human diseases and also on important entomological subjects closely connected therewith. Ever since its inception the Indian Research Fund Association has been financing, with the grants received from the Government of India, enquiries on entomological problems connected with the transmission and eradication of malaria, oriental sore, kala-azar, plague, etc. etc.

In 1913 Patton and Cragg published their comprehensive Text-book on Medical Entomology and the Indian Research Fund Association started the Indian Journal of Medical Research.

Prior to this the results of various enquiries were being published either scientific memoirs or reports of commissions, those directly connected with malaria appeared in the Paludism, a journal started for the purpose.

Work ón mosquitoes continued and in 1921 a taxonomic inquiry was started under Barraud, and in 1926 Puri started investigations on the comparative anatomy of the larvæ of the Indian Anopheline mosquitoes, and made important contributions. The Ross Field Experimental Station was started at Karnal to carry out investigations on the bionomics of mosquitoes and similar work started at Delhi. In Bengal and Assam Strickland and Iyengar were making valuable contributions to the problems of the distribution and habits of the different species of *Anopheles.*

In 1933 was published Christophers' volume of the Fauna of British India on Anophelini, dealing with 43 species and a year later Barraud's volume on Megarhinini and Culicini dealing with 272 species.

Insect carriers of other diseases had not been ignored. Ross worked in Assam to establish the mode of transmission of Kala Azar. However, it was not until the opening of the King Institute of Preventive Medicine at Guindy, Madras, that any entomological work in connection with Kala Azar was taken in hand. Patton in 1904 started experiments on the transmission of Kala Azar with lice and bed-bug. From 1924–32 the Kala Azar Commission, under Christophers and Shortt, carried out investigations on the bionomics and anatomy of *Phlebotomus argentipes*, a probable vector of Kala Azar and Oriental Sore. Sinton has made valuable contributions to the taxonomic studies of the Indian species of the genus *Phelebotomus.*

In 1933 the Sandfly fever became a problem of sufficient magnitude for the Military authorities in the North-West Frontier Province, to ask for the services of an entomologist and Puri studied the bionomics and control of these insects under field conditions. Once again, a year or so after the earthquake at Quetta, there was a severe outbreak of Oriental Sore and the Indian Research Fund Association instituted an enquiry under Smith to investigate the causes of the increase in the number of Sandflies and their control.

The close connection of rat with bubonic plague was known to the Moghals. However, it was not till 1898 that Simond had succeeded in transmitting plague from a stricken rat to a healthy one, through the agency of an infected flea. In 1904 Liston working in Bombay confirmed Simond's observations and in 1905 the plague Commission was appointed. Taxonomic work on fleas was done by Jordon and Rothschild in England; Bacot carried out researches on the bionomics of these insects at the Lister Institute; transmission experiment were undertaken at Bombay by Liston, Lamb, Kundhart, and Chitre.

In 1907 Mackie had found that the Asiatic Relapsing fever was transmitted by the body louse—*Pediculus*. In 1934 Typhus attracted attention and Mehta is doing useful entomological work in connection with this disease.

Christopher's early work on the anatomy and histology of tick, Patton's work on Muscidæ and Cragg's on blood sucking insects, particularly the bed-bug are worth mentioning. In 1914 P. R. Awati, the first 'non-medical' entomologist to join the Medical Research Department, started his work on the taxonomy of the genus *Musca* and the bionomics of the house-fly. Mitter worked on Culicoides and Brunetti (1911) described a number of new species of *Simulium*. Puri took up the taxonomic study of Simulidæ.

The credit for rapid and phenomenal progress in medical entomology and the excellent taxonomic work on insects of medical importance, goes mainly to medical men, particularly of the Indian Medical Service, who applied their well trained and disciplined intellect to the problems of entomology. Of the non-medical workers, Howlett, Barraud, Awati, Prashad, Senior-White, Iyanger, Puri and Mehta have produced work of value.

At the School of Tropical Medicine, Calcutta, Strickland was appointed the first Professor of Medical Entomology in 1922. Excellent courses in entomology are given and valuable researches conducted, on all aspects of medical entomology, especially on mosquitoes.

The entomological problems are becoming more and more complicated, and a pre-requisite for their successful solution is a broad and thorough entomological training. As Howard (1925) has pointed out there is need for the study of all insects of medical importance without an eye for immediate results, so that we discover all about them and then apply our knowledge for their control.

Veterinary Entomology.[1]

While India has made important contributions to Medical Entomology, exceedingly little work has been done on insects in relation to domestic animals.

Veterinary Entomology may be said to have taken its birth in 1893 with the fundamental discovery of Smith and Kilbourn, in America, that the tick *Boophilus annulatus* was the intermediate host of *Babesia bigemina*, the causal organism of the Taxas cattle fever. Two years later Bruce (1895), in Africa, found that the tsetse fly—*Glossina morsitans*, was responsible for the transmission of *Trypanosoma brucei*, the causal organism of Nagana. The causal organism of Surra, the foul disease of cattle, horses and camels in India, being a trypanosome—*T. evansi*, the attention of veterinary officers in this country was focussed on the discovery of its possible vector or vectors. This was the beginning of Veterinary Entomology in our country. With these researches are associated the names of Lingrad (1896), Gaiger (1911), Baldrey (1911), Cross (1921-22), Kahan Singh (1925-26) and others.

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[1] Based on information kindly supplied by Sen.

Lingrad had started collecting material for the study of Veterinary Entomology, and had obtained the collaboration of E. E. Austen of the British Museum, London, for the identification of flies. In 1907 Cecil Warburton published an account of the ticks 'Infesting Domesticated Animals in India'. In the same year Lefroy published an account of 'The Biting Flies of India'.

Howlett was appointed to study the order Diptera, including those that were parasitic on domestic animals. Isaac has contributed many papers on the *Tabanidæ*. Sen has done valuable work in veterinary entomology.

Veterinary Entomology has received much help from workers engaged on insects vectors of human diseases. It is to the researches of Christophers (1907) and Shortt (1936) that we owe our knowledge of the transmission of canine piroplasmosis (*Babesis canis* by *Rhipicephalus sanguineus*).

Howlett (1919) worked out a scheme for the creation of a separate organization to deal exclusively with the problems of Medical and Veterinary Entomology in this country. This organization was to consist of 10 officers and 46 assistants and the estimated cost was 4·5 lakhs as non-recurring and 2,80,000 as recurring expenditure. The First Meeting of the Veterinary Officers held in Lahore in 1917, considered and accepted the proposal and passed the following resolution :—

'That the meeting is in favour of the creation of a separate organization for the study of insect parasites of men and animals, the connection with the Civil Veterinary Department being on the lines suggested by Mr. Howlett.'

Nothing happened. The same question came up again before the Second Meeting of the Veterinary Officers held in 1923, and Bainbrigge Fletcher informed them that Howlett's proposals had been dropped, 'presumably on account of financial stringency'. The meeting then passed the following resolution.

'On account of the great importance of insects in the transmission of animal diseases, as causes of direct injury to live-stock in India, and the degree of specialization necessary for the proper appreciation of the various aspects of entomology, the staff of the Imperial Entomologist should be strengthened to the degree requisite for rendering assistance to investigators into the insect problems connected with animal diseases. Similarly, facilities should be rendered for the establishment of a staff attached either to the Imperial Entomologist, or to the Zoological Survey of India for the study of ticks and mites concerned with animal diseases.'

There was no immediate response. However, in 1933, the post of Entomologist was created at the Imperial Veterinary Institute and S. Sen appointed. We may say that the first brick has been laid and edifice of Veterinary Entomology has yet to be erected.

Lately the Imperial Council of Agricultural Research have sanctioned a scheme for the investigation of Warble fly.

In so far as the Provinces are concerned the results of the enquiries made may be summarized briefly—' No work undertaken '.

ENTOMOLOGY IN EDUCATION.

Entomology in Schools and Colleges.

Entomology has been the Cinderella of our educational system, and, so far, this important branch of human knowledge has been fairly effectively ignored in our schools and in our colleges. Save a few lessons in vernacular text-books, Indian boys and girls are taught nothing about insects. Our children do not rear caterpillars into butterflies as children do in other countries, nor are they seen with butterfly nets indulging in insect collection, which is considered by most Indian parents, a reprehensible manifestation of cruel propensities—*Jivhattia.* Thus from his very childhood an Indian boy learns to look upon insects as untouchable creatures to be abhorred and soon develops a marked entophobia. In our high schools the knowledge of insects acquired by those few—indeed very few, who take up hygiene as a subject of examination, is restricted to a few theoretical lessons about the disease carriers. In most cases this knowledge is confined to sketchy accounts and inaccurate diagrams in cheap text-books. With actual insects, living or even dead, the students make no acquaintance and in this they faithfully follow in the foot-steps of their teachers. Does it not seem strange that in courses of domestic economy for girls, a study of household pests should not be considered essential in a country where death spreading flies and mosquitoes breed freely, where weevils eat up grain, white ants damage wood and woolly bears spoil garments ? In the zoology course, at the intermediate stage the introduction to entomology is confined to an elementary account of the cockroach and perhaps the life-history of the mosquito. In our Universities the number of students taking up zoology is hardly 5 per cent. At the degree stage of zoology course a study of the mouth parts and the classification of the groups into orders of Linnaeus is considered sound education.

Some of the Indian Universities are now providing training at the M.Sc. stage to those rare beings who select Entomology as a ' special ' group. But often the teaching, equipment and atmosphere provided for such a training leave much to be desired.

Research work in Entomology is recognized for the research degrees, and useful entomological work is being turned out by some of our Universities, and Insects are very often selected for cytological investigations. Of the students of zoology who go abroad for advanced training, a very large proportion select entomology for their special study. Valuable though a training in research is, it cannot take the place of fundamental training in entomology, which has become so vast as to merit a special treatment, and an independent status of a 'full subject'.

Entomological Education in Agricultural Colleges.

Till 1919 the position of Entomology even in the Agricultural Colleges of this pre-eminently Agricultural country was so unsatisfactory that the Third Entomological Meeting held in February 1919 discussed the question and made the following recommendation :—

> 'Considering the great economic importance of insect pests to Indian Agriculture we recommend that all Agricultural Colleges should make provision for the teaching of Entomology'.

Our Agricultural Institutions had been fashioned after the pre-war British pattern and it is not surprising that in 1919 the atmosphere was so adverse to Entomology that even the devotees of this science had not the courage to take a bold stand, and diluted their above recommendation by a rider. They stated: 'the aim of teaching Entomology in Provincial Agricultural Colleges should be to give the students a sufficient knowledge of entomology to be able (1) to recognise the common pests and to know something of their life-history and the control measures applicable to each, and (2) to be in a position to report intelligently regarding the occurrence of any unusual pests'. Such a training could not possibly be termed anything but 'First aids in Agricultural Entomology'. The explanation for this attitude was that in the Agricultural Colleges the aim was to train farmers and fruit growers and not entomologists. It was evidently no concern of the entomologists as to how and where the entomological workers were to be trained ? Perhaps at that time the dominating idea was that an entomologist was born and not made. In his scheme of organisation of Entomological Research, Fletcher had not included entomological teaching at the Central Institute, and had consigned training in entomology in the Provincial Agricultural Colleges to the cares of subordinate entomological workers or to the visiting lecturers, delivering a few lectures.

Since then, thanks to the efforts of provincial entomologists, the position has greatly improved. All those Agricultural

Colleges which prepare students for the degree examinations in Agriculture give some training in Entomology, but with the exception of one or two colleges the standard of training is still very low. Only in a few Agricultural Colleges entomology has been regarded as of equal merit with botany and chemistry and is included among the 'principal' subjects. It is not often realized that knowledge which is superficial soon peals off and what does not soak through sufficiently deeply is lost immediately.

The University of the Panjab grants a degree of M.Sc. (Agric.) in Zoology-Entomology on the combined results of a written, and a practical examination and research thesis.

The number of men suitably qualified to conduct entomological investigations falls much short of the demand.

Entomology in Medical and Veterinary Colleges.

Like our Agricultural Colleges our Medical and Veterinary Colleges have also been modelled after the pre-war British pattern. We, however, forget that while insects may not be of much importance in a cold country such as England, the case of India is very different. According to Mackie (1925) 'the unhealthiness of the tropics and sub-tropics is not a question of heat and humidity or such physical states, but is due almost entirely to the diseases which these conditions foster, so that if we rid India from the insect borne diseases, we shall go far to bring her mortality into line with that of temperate countries'. Insects are responsible for most of the diseases which appear in epidemic form in India among human beings and domestic animals, yet a sound knowledge of the insect-carriers of diseases, is not considered to be an essential feature in the medical and veterinary education of our country. It is true that medical entomology has a place in the curriculum of study in Institutions training men in Tropical Medicine and Hygiene. But is that enough? At present entomology has no place in veterinary education.

IV. IMPORTANCE OF ENTOMOLOGY TO INDIA.

Sir Thomas H. Holland addressing the Royal Society of Arts (1926) on the 'Organization of Scientific Research throughout the Empire', said :—

> 'Anyone who has lived in a tropical country will be able to appreciate, as a consequence of painful personal experience, the importance as well as the magnitude of measures intended to stamp out noxious pests or to encourage friendly insects. Among the special branches of sciences of economic value to an empire with large possession within or near the tropical belt, I should regard entomology as perhaps first in importance'

Sir Mirza Ismail, Leader of the Indian Delegation at the Inter-Government Conference on Rural Hygiene, held at Bandoeng in 1937, thus expressed the condition in our motherland :—

> ' Of the formidable list of diseases with which India is afflicted, malaria is certainly the one which exerts the most adverse influence on the health and prosperity of her people. Although less dramatic in its immediate effects than the great epidemic diseases, such as, plague, cholera and smallpox, malaria is a relentless scourge which is responsible for incalculable suffering and economic loss. It has been estimated that some 100,000,000 people in India suffer yearly from malaria and that, of these, at least 1,000,000 die from its direct effects. The debility, poverty and apathy caused by this disease are factors of magnitude in retarding the national, social and economic progresss of the country.'

There is evidence to show that malaria was the cause of the decay of Greek and Roman civilizations and it is not surprising that *Anopheles* is the greatest obstacle in our progress.

According to Mackie (1925), 'The amount of disease, invalidism and death which occurs every year in India from the bites of insects is enough to stagger humanity '. He maintains that the ' enormous economic burden from the incidence of preventable disease which India has to bear is sufficient to prevent her rising to the position of importance to which her large population and great resources entitle her '. And, in India two-thirds of the preventable diseases can be attributed to insects.

In 1920 Fletcher made an estimate of the loss to India caused by the insect pests of sugarcane. ' Taking the conservative estimate of 10 per cent. of damage by insect pests (and this is most certainly not too high a percentage) ' he placed the annual loss at over 330,000 tons of sugar, ...' roughly an annual sum of three hundred millions of rupees worth of wealth of the country goes into stomachs of insects instead of into the pockets (if they have any pockets) of the people '.

According to the Report on the Marketing of Wheat in India (1937), the total wastage caused by wheat weevils is ' not less than about 150,000 tons, representing 1·6 per cent. of the average crop '—and on the basis of the upcountry prices of 1935–36 the loss has been estimated at about Rs.97 lakhs. This is but loss to one food grain, viz. wheat, alone. And it is certainly a very modest estimate, because Dean (1928) states that ' such damage is frequently estimated at 5% and that the total value of the losses caused by insects injurious to stored grain and milled products in the United States of America amounts to two million dollars annually '.

The loss caused by one insect—the Ox Warble Fly, to the hides produced in this country is 1·5 crores of rupees per annum. According to Fletcher (1921), at a very conservative estimate, the annual monetary loss from insect pests to domesticated animals in India exceeds Rs.3·8 crores.

According to Sir Walter Morley Fletcher (1931), at a very modest estimate, the losses caused to India by insects that attack crops, timber, and animal products cannot be less than 200 crores of rupees and a loss of over a million and a half of human lives. (These figures had been officially collected for the Imperial Entomological Conference.) However staggering this may be, it cannot be considered an overestimate. Hinds (1934) estimates an annual loss to North America from insect damage at $ 2,500,000,000, and according to Kavalev (1930) in the United States of Soviet Russia '..... the enormous damage inflicted by pests upon the agriculture of the Union is estimated at over 2,000 million roubles every year '.

According to Hinds (1934) loss from insects has increased during the last 50 years and is likely to increase in the future. Every day that passes the insect problem is becoming more and more serious. It is because every step in the progress of civilization is favourable for our insect foes. The methods we employ to produce food in ever increasing quantities, to store it more and more, to produce varieties which are superior and give higher yield but are not resistent to pests, and our modes of life help insects to multiply. Facilities of transport such as motor cars, railways, aeroplanes help in insect spread.

It has been said that 'insects have been responsible for more destruction of property and loss of life than caused by all wars, floods, earthquakes, fires and famines in human history', (Hinds, 1934). A bold statement but true. On the other side we have products of insect activity which are source of wealth. India holds monopoly of lac, and silk and honey are of equally great importance.

There cannot be any doubt whatsoever that among sciences of economic value in India, entomology must take the very first place in importance; unfortunately it occupies at present the very last.

V. FUTURE OF ENTOMOLOGY IN INDIA.

That is the present position. Now how about the future ! India has entered upon a new form of Government, with increased representation and increased responsibilities. Democracy at best is a very expensive form of administration and for all beneficient activities and developments money is essential. Retrenchments and reductions in the cost of administration are mere palliatives, they do not provide a cure. In most parts of the country the burden of taxation on land is already so high that no further increase is possible. In fact our farmers are so heavily under debt that they are crying for immediate substantial relief. In the industrial field the competition is so keen that some form of protection or subsidy is demanded. In the circumstances we must either tap new sources of income—not an easy task, or we must stop wastage. India is paying a tribute of 200 crores of rupees to the demons '*Ṣaṭpada*'. What policy of defence should we inaugurate against this enemy which is destroying life and property on a scale far in excess of what any human foe can destroy. To reduce this enormous waste of our national wealth, is one of the most important and urgent problems which India has to face. It is for us to find a solution, but we are greatly handicapped. The insect problem has not yet received the recognition that its enormity demands. The number of those interested in entomology, amateurs, teachers, students, workers in pure entomology, agricultural, forest, medical, veterinary and industrial entomology, does not exceed 125. Thus for every 2·5 million people of India there is one person interested in insect study. At a very liberal estimate the total expenditure of all entomological activity—teaching, research and pest-control, would not exceed 15 lakhs a year. Against this, about 1932, the normal budget of the U.S.A. Bureau of Entomology alone was $25,000,000 and on 1st March, 1930, the total classified personnel of the Bureau was 515, and there were 100 field laboratories in U.S.A. and other countries. In addition to this, all States and all Universities and Agricultural Colleges employed large staff of entomologists.

PUBLIC AWAKENING.

Before any progress is possible the population at large must be convinced that insects are its bitterest foes. We must have the public to appreciate the fact that it is of vital necessity that something immediate must be done to stop the inroads of insect pests. Our public must learn to appreciate the true value of the study of insect life. Our legislatures must learn to acknowledge that the insect problem is one of the problems on the proper solution of which the future of this country depends, and that applied entomology must develop if man is to gain health, peace and prosperity. It is the duty of the entomologists to educate the public and we must employ every possible method to achieve this end.

By every means possible we must greatly increase the number of workers both in pure and applied entomology. Public education will be a means to this end, and public awakening will increase the number of amateur workers, the class which has done most magnificent service to entomology in the past. Funds have to be obtained from the Legislative Assemblies and therefore we must have the public behind us and the legislatures on our side.

FUTURE OF ENTOMOLOGY IN EDUCATION.

At the close of the Great War Sir Harry Johnston wrote an article in the Nineteenth Century Magazine on 'The Next War', a war against insects. In this article he rightly pleads for a wider knowledge of entomology. He boldly states that 'the whole curriculum of our schools wants overhauling and that instead of Euclid should be taught entomology or the science of insects ; instead of puzzling over Algebra boys and girls should be well-grounded in elementary zoology, botany and chemistry'. In fact insect horrors so impressed him that he wanted 'all public servants of every degree and every branch of state employment' to pass an examination in entomology.

We cannot make progress unless in the words of Howard (1925) 'We uncloister our schools and colleges, not only the minds of the students but especially the minds of the teachers'. As to what should be accomplished I cannot do better than quote from Gossard (1925) who gave the following advice to the Section on Education, Extension, etc., etc., of the 10th Annual Meeting of the Pacific Coast Branch of the Association of Economic Entomologists in the United States of America :—

> 'This section should be specially devoted to the consideration of entomology as a necessary part of education or of nature study in rural schools, grammar schools, junior and senior schools ; the inclusion of a well chosen entomological section in the Boy Scout Manual and in the publication of Campfire Girls : to secure better than casual notice on insect subjects in such papers as the Youth's Companion, Boy Life and in the standard magazines which contribute most largely to moulding the world's thoughts. It should endeavour to increase the use of entomological toys and games and if possible add to the entomological education of the clergy and those religious orders which participate in large degree in general education of the public . . . .'

No better programme could be laid for this country. Ghosh (1919) brought the same question before the 3rd Entomological Meeting and argued that no rapid progress in control of pests and noxious insects was possible unless the people of the country became 'Insect minded' and, therefore, he considered it necessary that information concerning insects be made a compulsory subject for children in primary schools in India, and advocated that the readers for use in these schools should contain simple accounts of some of the insects commonly found in the Provinces concerned, and he emphasized that Entomology should figure prominently in all courses of nature study and advised the education authorities to enlist the help of entomological workers in the preparation of suitable readers and text-books. The meeting unanimously passed several resolutions on the subject, but so far they have remained mere pious hopes. Entomology must take its rightful place in our schools.

Entomology in General Zoology Courses.

The departments of zoology in the Universities in India have to reconsider the whole question, and impart such entomological education at all stages of a zoology course as the importance of this subject demands. We must bring education more and more in line with our needs. It is claimed for entomology that it provides full scope for the development of mind, and no other branch of zoology has such wide application to human affairs.

Entomology in Agricultural Colleges.

Although great progress has been made in some of the Universities of India to give entomology its rightful place in the curriculum of agricultural studies, yet much remains to be done. There was a time when an agricultural entomologist could be considered competent to do his work well if he was familiar with crude morphology and general classification. But gone are the days of 'catch and kill' or 'cut and burn', and we have to aim at prevention rather than cure. Insect control of today is not an easy matter, what we once thought simple is becoming more involved. Further improvement of the status of entomology in the course of agricultural studies is greatly needed.

Entomology in Medical and Veterinary Colleges.

Entomology has yet to fight its way into the curriculum of studies in our Medical and Veterinary Colleges. In a country where the so-called tropical diseases are responsible for at least two-thirds of deaths, a study of the carriers of these diseases cannot be ignored. In our country every medical institution should be a school for tropical medicine. Let us hope that the difficulty of finding time for this important branch of preventive medicine will not be insurmountable, and if it is found that the Medical curriculum is already too congested, is it not possible to make some knowledge of insect structure, bionomics and classification a qualification for admission to a Medical College ?

At a meeting of the Animal Husbandry Wing of the Board of Agriculture held in 1934, the question of entomology in Veterinary colleges was considered. The opinion was favourable, although it was pointed out that in a three years' course it will not be possible to deal with the subject very thoroughly. Let us hope that something material will result.

Training of Entomologists.

The important question of the training of entomologists, as distinct from including entomology in the education of all classes of people, has been occupying the minds of teachers in all countries. The fifth Entomological Meeting held at Pusa in 1923 unanimously passed the following resolution moved by K. Kunhi Kannan :—

> ' That this meeting recommends to the Indian Universities that the subject of Entomology be taught as of equal rank with other branches of biological science in the courses of studies for the examinations of the Universities for the degrees in Science including Agriculture.'

The International Congress of Entomology, held at Zurich during 1925, discussed this question. The same question came up before the Congress of Imperial Economic Entomologist, 1925, and was further discussed in the Third Annual Meeting of the British Zoologists held in January, 1926, when Prof. Stanley Gardiner moved the following resolution :—

> ' That on account of the growing importance of Entomology fuller facilities for the teaching of Entomology should be provided by the Universities.'

Once again the Imperial Agricultural Research Conference, 1927 recommended :—

> ' In view of the fact that the progress of Agricultural Entomology is to a considerable extent dependent on the advancement of the science of Entomology in general, it is very necessary that more attention should be given in Universities to research and teaching in pure Entomology, which are at present hampered by the lack of necessary funds.'

I do not wish to dilate on this point. I will only say that there is growing need for a better, broader and sounder training in Entomology and as a basis a wider training in Biology, which is being greatly neglected. The Universities can play a very important part in the training of entomologists, by improving the status of Entomology in their zoology course for the degree examinations and in post-graduate courses.

FUTURE OF INSECT TAXONOMY IN INDIA.

Now I come to another most important question. I would like to repeat that to be able to know precisely and definitely what insect is under investigation, and to be able to talk about it and write about it so that all others understand, is of fundamental importance in every sphere of insect study and more particularly in applied entomology. It is not every mosquito that is the carrier of malarial parasites, nor is every fly a warble-fly. Even closely related species may have widely differing habits, and widely differing behaviour, and control operations based on imperfect knowledge of the identity of a pest may mean entire waste of enormous energy and wealth. I may perhaps illustrate this point by an example. Not very long ago the borers of sugarcane and related plants were all placed under one species, and such control measures as sowing of maize as 'trap crop', to protect sugarcane from borer attack, were advocated. It was only after a carefully taxonomic study had been made that the absolute futility of such recommendations became apparent. The borer pests of sugarcane would not feed on maize. Such instances can be multiplied indefinitely.

The necessity of developing Taxonomic Entomology within the Country.

It is becoming more and more evident that taxonomy divorced from other branches of entomology cannot reach stability. Even in the case of some of our most important insect pests the past methods have led to a great deal of confusion. For instance, in practically every case the phases of the migratory locusts were named as different species. Our very serious and common pest of sugarcane in India—*Pyrilla*—described from pinned specimens was split into three species on the basis of small colour differences which have proved to be normal variations (Pruthi, 1937). Taxonomy can no longer be regarded as mere christening of dead insects pinned, staged or preserved. Untold confusion has been caused by this attitude. With the development of applied entomology the responsibilities of taxonomy have increased. Taxonomy must be unfettered from its present bondage and allowed free vision much beyond the cabinets and museums. It is very necessary that taxonomy must be broad based and we must recognize that life-history studies, ecological observations, facts of geographical and season variations all have an important bearing on insect identification. For such a complete study of insects it is necessary that taxonomy must go hand in hand with other branches of entomology, hence the necessity of developing taxonomy within the limits of a country.

Further, the difficulties of depending on an outside agency for taxonomic work are great, in spite of the fact that we have quick means of transport and communications. I shall illustrate my point by a specific instance.

About 1927 some insects were sent abroad, and their identifications were received after about a year. There were a few new species to which names had been given, with the remarks that their descriptions would be published; but these have not been published so far. Ten years have gone by and, as we have not been able to obtain proper identification, our publication has been held up. In the meantime another difficulty has arisen. *Another consignment of the same material* was sent to the same agency in 1929. As the first expert had given up work on the group, this second consignment was handed over to another taxonomist and his identifications, received recently, do not agree with the previous identifications. If it had been possible to identify this material within the country, all this delay of years in the publication of important results of wide application would have been avoided.

Imperial Institute of Entomology and Entomology in India.

While on the subject of the development of taxonomy, it will be an unforgiveable omission if no mention is made of the assistance given by the Imperial Institute of Entomology, London, to workers in India. The publications of the Imperial Institute, the two series of the Review of Applied Entomology and the Insect Part of the Zoological Record, rank among the most important publications of international utility. Besides, the Institute is rendering most valuable services in the identification of insect specimens. The condition of insect collections in this country being what it is, the Imperial Institute and the British Natural History Museum have, for years, to play an important part in fostering taxonomic work in India. During the two years 1934 and 1935 the Imperial Institute of Entomology identified for India (including Burma) 1,670 specimens. How hard pressed the Institute is, will be evident from the fact that the number of insects received for identification had risen from 101,093 in 1930 to 4,926,060 in 1935. With the rapidly growing interest in entomology and particularly in applied entomology, this demand is likely to increase greatly. In addition to the staff of seven expert Entomologists on the permanent establishment, the Imperial Institute has found it necessary to seek outside help and have made arrangements with 64 specialists, in different parts of the world, to identify insects. Although this organization is the largest of its kind in existence, even so, the Institute is unable to meet adequately the demands made upon it. A mild warning has been issued by the Directorate that they have now almost reached the limit of work that is possible with their present resources.

It is not only the Imperial Institute of Entomology that is working to.the utmost limits of its resources, the world position in Taxonomic Entomology is still more unsatisfactory. Of late many of the entomologists in Europe and America have drawn attention to the imminent danger of a break down. The resolutions and recommendations of the third International Congress of Entomology held at Zurich in 1925 may be taken as an index of international opinion on this question :—

> 'An enormous extension in applied entomology has recently taken place throughout the world. This has necessitated, as a first step, the exact determination of an immense number of insects. The result has been to show the utter inadequacy of the present means of undertaking such work '. . . 'Everywhere the systematic specialist is overburdened and his load has now become an intolerable one.'

Attention is also drawn to a very interesting and thoughtful address by Walther Horn (1928) to the fourth International Congress of Entomology, on the 'Future of Insect Taxonomy', where the position of Taxonomic Entomology in the world has been discussed.

The situation does not appear to have improved during the last 12 years and Neave in his address to the Royal Entomological Society of London (1935) laid great stress on further development of taxonomic work. He stated : 'At the present time the ever growing demand, rising from the innumerable investigations on insect pests and their insect parasites that are in progress all over the world, is quite impossible of satisfaction with the existing staff. It is, therefore, incumbent upon the Governments to spend more money in this direction (taxonomy) if they are to derive full benefits from the funds invested in solving economic problems in entomology '.

The fourth Imperial Entomological Conference held in London in September, 1935 unanimously demanded 'the utmost possible extension of the systematic work '. It was pointed out that there was 'still lamentable ignorance of such economically important group as the parasitic Hymenoptera and Diptera and the termites ' (Neave, 1935).

It is time that we entomologists in India carefully considered the position in relation to foreign workers and particularly in relation to the Imperial Institute. The contribution of our country to the Imperial Institute is indeed meagre—£200 a year. It should, however, be possible for us to render effective co-operation otherwise. We must develop taxonomy in this country and some of our taxonomists should specialize in certain groups and thus reciprocate the valuable assistance which has been given to us for so long by the Imperial Institute and other workers. Further, it is necessary for establishing taxonomic entomology on a sound footing in India, that a scheme of deputing at the Imperial Institute a number of young Indian entomologists for the study of special groups, for terms of years, be vigorously advocated. This will be for the mutual gain of the Imperial Institute and Entomology in India. Similarly, students going abroad for entomological education should be encouraged to do taxonomic work on Indian insects.

Insect Collection.

Taking into consideration the area of our vast country and tremendous variety of insect life, and recognizing the fact that perhaps we do not know even one insect in sixty, our task is stupendous. We require an army of enthusiastic, careful collectors and investigators. The only paid staff for purely taxonomic work in Entomology in India consists of one Assistant Superintendent in the Zoological Survey of India and his small staff and one Systematic Entomologist attached to the Forest Institute, Dehra Dun. How utterly and hopelessly inadequate this staff is, needs no advocacy. Investigators on medical entomology have done excellent taxonomic work on small insect groups of medical value and some taxonomic work has also been done in Agricultural Institutions and the Universities, but the fact remains that today most of our taxonomic work is being done by experts, outside the country.

In the past in every country taxonomic entomology has been the outcome of the enthusiasm of amateurs and our country has been no exception. We owe a deep debt of gratitude to those enthusiastic workers, including clergymen, army men, medical men and others, who while engaged in their own pursuits, found time to collect insects and study them. Most of these voluntary workers have been Europeans, particularly Britishers. Among early collectors of Indian insects and taxonomists one looks in vain for an Indian name. Even today there is hardly a country-man of ours who is known to collect insects as a hobby. Time has come when we should shoulder this burden, and it is our duty to encourage amateur entomologists.

It is not every one interested in insects that becomes a keen collector. It is therefore essential to promote the habit of insect collecting from the very childhood and for this purpose we must go down to schools. Insect collections must form an important part of nature study and every teacher passing through a training institution must provide proof of his being able to encourage insect collection by personal example. It has been claimed for entomology 'that it can procure the maximum delight for the mind' and believing in this we must initiate others to the delights of entomological pursuits. Insect collection should be as interesting a hobby as stamp collecting and infinitely more useful.

According to Sharp (1919) 'This period ought in the history of Entomology to be marked as the age of collecting', and he states that 'to get together a collection of all the insects of a limited region is merely to lay one of the foundation stones of science of Entomology in that region'.

Insect Survey.

Geographical and ecological distribution is in itself a fascinating subject and it is of utmost importance in applied entomology

—medical, veterinary, agricultural or forest. Epidemiology is already considered a very important branch of medical science and it is being recognized as of great importance among workers in every branch of applied entomology. A complete survey, geographical and ecological, is necessary for a proper study of the epidemiology of all pests, and must be encouraged by every possible method. In addition to pest surveys, general insect surveys are necessary as these form the foundation of taxonomic work. All institutions teaching advanced entomology should organize such surveys and by every possible means such surveys should be encouraged.

Universities and Taxonomic Entomology.

Our Universities can play a very important part in conducting insect surveys, in getting together large collections of insects and in developing taxonomic entomology. Every University in India where there is a Department of Zoology should undertake a thorough entomological survey at least of a group of insects or a geographical region or an ecological complex. We shall thus lay the foundation of excellent taxonomic work in all parts of our large country.

It should be recognized that taxonomic work is of fundamental importance in the training of an entomologist whatever line of work he may take up later on. Before an investigation is started, may it be in bionomics, physiology, ecology, distribution or applied entomology, we must be able to answer precisely, definitely and without a shadow of doubt the question: 'What is it?' Let every student of entomology develop sufficient keenness and enthusiasm for taxonomic study, so that he realizes the importance of this question. Not only should all taxonomic work of merit be recognized for all University degrees obtained through research but it should be specially encouraged. To further emphasize the point I would draw your attention to the following resolutions moved by Horn-Escherich—Nuttal, at the International Congress of Entomology (1925). That:—

> 'The teaching of Systematic Entomology at Universities be adequately provided for by the establishment of chairs especially devoted thereto.'
>
> 'The meritorious systematic work should be regarded as qualifying candidates for ordinary and advanced degrees at Universities.'

Museums.

Taxonomy and insect collection go hand in hand. In order to obtain quickly an accurate determination of insects, properly classified, named collections for comparison are absolutely essential. In every province and Indian State there should be an Institution or a Museum, with an adequate staff of specialists and technical Assistants for taxonomic work. As long as this is not done taxonomic entomology must remain undeveloped. Such an Institution will serve as a repository of collections of all species in a particular area, will exchange duplicates with other similar Institutions and thus taxonomic entomology all over the country will develop. Whether these museums are independent institutions or form part of Agricultural Colleges or the Zoological School of a University is immaterial.

Further, we should develop at least one National Museum which should have as complete a collection of Indian insects as possible. India has lost almost all types of insect species so far described. Let us have the next best—carefully determined, properly labelled, authentic specimens of all our insects, so that future investigators have facilities for work. We must make a vigorous co-operative attempt to have at least in one place as large a collection of species described from India as we can.

OTHER LINES OF RESEARCH.

I have laid special stress on taxonomy, but not because I consider it the be all and end all of entomology but because this field of study is not receiving in India, and in fact anywhere else, the attention which its magnitude and importance demand and deserve. In our country there is need for research in every branch of entomology. We must study the morphology of Indian types and place in the hand of our students books dealing with the structure of insects that exist in this country. In Entomology we should have Monographs of the type issued from Lucknow (edited by Bahl). Our studies in bionomics have been confined to few pests and a great deal remains to be done. Fletcher's studies on the life-history of Indian Microlepidoptera just indicate what is required for all the groups. Insect psychology, or to use a simpler language, studies in insect tropism or behaviour, are of utmost importance. If we can only discover what force guides the female Carpet beetle—*Anthrenus*, an open air insect to enter a house, however well screened with wire gauze, reach the deepest recesses of cupboards, creep in through narrowest chinks, and get at woollen garments, or, if we can discover what attracts the female *Anopheles* to man, we would be well on our path to a satisfactory control of most insect pests. Insect ecology holds the field today and it must play an important part in placing in our hands facts on the basis of which we could predict insect abundance and outbreaks. Enormous work is needed in this direction. Biological control of insect pests is yet in its infancy in India. We know very little about enemies of insects and their mass multiplication. We know still less about insect diseases. Insect pathology is a young science and full of promise. And finally we must not ignore the application of mathematics and statistics to our science, use of logarithmic tables has entered the field. The demand is so great and so much work is to be done that we cannot get enough workers and enough facilities for the study of all the different aspects of insect life.

FUTURE OF APPLIED ENTOMOLOGY.

As a result of general awakening to the applied value of entomology and improvement in the teaching of entomology, it is expected that more money and more men will be available for researches in this direction. In every branch of applied entomology there is need for great and immediate expansion. If India is to rise then her insect pests must go under. Any money spent for the study of insect pests will more than repay itself. In every province and in every Indian State more men are required for investigation on insects of agricultural, medical and veterinary importance. In every province an entomological section of the Department of Agriculture is a necessity. Every Medical Department and Veterinary Department should have fully trained men available for investigation of local problems and control of disease carriers. Our Forest Entomology needs strengthening. I wish to draw your particular attention to one danger. The line between pure entomology and applied entomology has no thickness, but very often an applied worker has to stop work of great importance, because the pay-master considers it pure science and will not see its future possibilities. This is the case all over the world, but more so in India. The consequences of such a policy are as serious for the development of science as for the intellectual development of the workers.

ENTOMOLOGICAL LITERATURE.

It can hardly be disputed that no branch of knowledge can progress without literature. In this respect entomology in India is very badly placed. We have no literature worth the name in any of the vernaculars of our country. Without such a literature we cannot interest our people in this very important science. There is need for simple, popular books on insects in general and also on insects which do damage to our crops, our goods, our animals and injure ourselves. Since 1909 when Lefroy wrote his 'Indian Insect Life' no comprehensive book has been published on insects of India, and Lefroy's book has been out of print for years. Thus Indian students of entomology have to fall back on books dealing with insects of other countries. It will be a fit tribute to the memory of Lefroy, who did more for entomology in India than any one else, if his book is revised and brought up-to-date. There is need for scientific treatise on applied entomology with reference to the particular conditions of the country. Abundant material is available and time has come when this work should be taken in hand.

There is enormous literature scattered in numerous journals and publications dealing with Indian insects and a complete bibliography of this literature is one of the greatest needs.

The brief and incomplete outline of the history of Indian Entomology that I have placed before you must have shown that there is need for an authentic history of Entomology of this country. Books printed elsewhere ignore our country completely, we must make up this deficiency ourselves.

We must vigorously push forward the publication of the 'Fauna of British India' and Catalogues of Indian Insects.

INTERNATIONAL POSITION OF ENTOMOLOGY.

Entomology has long ceased to be a subject of purely national interest and is becoming more and more a subject of great international importance. Insects recognize no political barriers nor separate governments. Today they conquer one country tomorrow another. Modern means of transport—railways, motor cars, steamships, airships, aeroplanes—have made the spread of insect pests a matter of international consideration. India has already been invaded by San Jose' Scale, American Blight, Potato Tuber Moth, and Codling Moth, to mention but a few. Further, insects such as the locusts born and bred in one country may fly over to distant lands. Nations are awakening to the international importance of insects, and Locust research and control are already in operation on international basis. Therefore, an entomologist, to whatever country he may belong, has to take an active interest in the international entomological problems. With ever increasing quarantine restrictions and legislative measures against the spread of insect pests, demands for certificates of freedom from pests, notification of outbreak of pests on international basis, India must develop her entomology so that she can take her proper and rightful place in the international assembly of entomologists. You will be interested to know that the Imperial Institute of Agriculture, Rome have announced that Radio communiques of that Institute will be transmitted for English knowing people on Thursdays.

So far we have gone on the presumption that an insect which can exist in one country can also exist in another and a pest of one country can assume the status of a pest in every country. It is true that some insects have become wide spread in a comparatively short period of time, for instance the San Jose' Scale; and yet there are others which have not been able to spread even into neighbouring territories and adjacent localities. Without a thorough study of the ecology of a species it is impossible to predict its behaviour and in the meantime much money is being spent at our quarantines in killing insects which are either already dead or which if introduced to new locality are likely to die of their own accord. India if she is to protect herself against foreign pests efficiently then she must study the question and develop a well organized and well trained quarantine service. *This important task can no longer be left in the hands* of laymen.

ENTOMOLOGICAL JOURNAL.

For growth of entomology a periodical devoted entirely to the publication of research work in this science is essential. At present there is no such journal in India. Most of the papers on entomology, therefore, find their way into periodicals dealing with general agriculture, forestry, medicine and veterinary, or what is still distressing, into the proceedings of the various Societies and Academies and the publications of the various Universities, intermixed with subjects which are not of the remotest interest to an entomologist.

Sir John Russel mentions in his recent report that 'it is comparatively rare to find references to Indian investigations in books published outside India'. The scattered manner in which we publish the results of our researches is certainly one of the reasons for this unfortunate neglect. Sir M. Visveswaraya in his Presidential address before the Indian Science Congress of 1923, deplored the tendency to multiply our journals, which leads to defusion and disorganization, instead of co-oridnation and co-operation. He emphasized the need of one accredited journal or publication for each branch of science, which will command respect in other countries. A rough computation made reveals *the fact that no less than 80 different publications in India include* material on entomological subjects. Even if half of this material is of general character which should legitimately find its place in popular periodicals, the position still remains unsatisfactory. Is it possible for College and University libraries to obtain all these journals, or is it possible for any research worker to keep track of the literature in the special branch of knowledge in which he is interested ? The Scientific Abstracts issued by the National Institute of Science in India and Lists of Publications on Indian Entomology published by the Imperial Council of Agricultural Research, are very incomplete because even the Zoological Survey of India and Imperial Agricultural Research Institute do not get many of the publications appearing in the country which contain valuable entomological material. Workers in medical entomology advocated the desirability of a separate entomological publication very early and in the very first meeting of the Governing Body of the Indian Research Fund Association the question of publishing an Entomological Bulletin was raised. Evidently the Entomologists being in minority lost the point and it was decided that entomological papers should be published in the Indian Journal of Medical Research. Hundreds of pages of this Journal have been devoted to first rate entomological literature, dealing with physiology, morphology, ecology, bionomics, embryology and taxonomy, intermixed with, for instance, such subjects as Birth and Marriages among Brahmans. Thus most valuable entomological material has become out of reach of many entomological research workers. Similarly, we find excellent entomological literature in agricultural and forestry journals, buried among heap of other matter.

Almost two decades back the following resolution was passed by the Third Entomological Meeting held at Pusa (1919) :

> 'The Third Entomological Meeting is of opinion that it would be desirable to have a Journal solely devoted to Entomology and Government should undertake publication of it

The details were left to a Committee, but as most of the members proposed for this Committee declined to serve on it, the matter had to be dropped.

Lately the Forest Entomologist has at last been successful in getting a separate publication on Entomology.

It is evident that a periodical which should collect the best of all the available entomological material and publish it in a form readily accessible to all entomological workers, would be eminently desirable and would meet a real and pressing want. Such a periodical besides collecting valuable entomological material in one place, will enable workers to find out what others are engaged on, co-ordinate work, excite healthy emulation, and let the outside world know what Indian Entomologists are doing.

ENTOMOLOGICAL SOCIETY.

So far no serious attempt has been made to have an organization to provide a common meeting ground for all those interested in insect study. The nearest approach were the Entomological Meetings arranged by Fletcher, the fifth and the last of which was held in 1923 at Pusa. It is after 15 years that we meet again in this Section.

While in the year of grace 1938 we have to consider the question of an Entomological Society for India a number of Entomological Societies have completed one hundred years of active work, and some have a still longer record of useful service.

It will not be without interest to state that the first Entomological Society to be founded was Societas Aureliana of England, established in 1745. The Societas Entomologica, which developed into the Royal Entomological Society, London came into being in 1806.

Entomological Societies were established in America in 1842, in Russia in 1861, in France 1867, in Canada 1868, in Argentine 1873. The Royal Entomological Society of Egypt was established in 1907.

It is most necessary for the future development of our science that a powerful, independent body of Scientific opinion be created to foster the growth of entomology in our country. An Entomological Society of India with branches all over the country is greatly needed.

GENTLEMEN, 'much has been done but much more remains to be done', and let us turn to our task with the full conviction that :—

> 'The entomologists are the men on whom the world must depend for much of its future prosperity', Howard (1925).

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SECTION OF ANTHROPOLOGY

President :—B. S. Guha, M.A., Ph.D., F.N.I.

Presidential Address

THE RACIAL COMPOSITION OF THE HINDUKUSH TRIBES.

The region south of the Hindukush and Karakoram mountains and lying approximately between lat. 35°–37° N. and long. 70°–76° E., occupies a strategic position in the racial geography of India, for, as seems certain, it is through the passes of the high mountain chains which guard her north-western boundaries that the northern steppe folks reached India; and in the difficult valleys flanked by lofty spurs and drained by the tributaries of the Upper Indus we still find the remnants, if not of the main invaders, at least of those of kindred tribes who came in their wake.

The earliest references to the tribes living in this region are given by Herodotus, who speaks of 'Other Indians' as occupying the frontiers between Kaspatyros or Kashmir and the Paktyan country or Afghanistan (III, 102–105). Strabo (XV) and the elder Pliny (Natural History, XI, 36), however, specifically mention Derdaï or Dardae as the name of the tribe, and refer to Megasthenes as their authority. The latter must have had in his mind the Sanskrit name 'Darada' mentioned in the Puranas and the Epics in a generic sense for the people of the N.-W. Himalayan region, who were warlike and among whom the Buddha had sent his missionaries.

In modern times the earliest mention of these tribes was by Moorcroft, who, in 1821 first drew attention to the Dards. Following him Vigne in 1835, and Cunningham in 1846, travelled through Baltistan and published some accounts of the tribes living there. In 1847, Young and Agnew crossed the Indus at Bunji and reached Gilgit. Unfortunately the report of these two intrepid officers was lost, owing probably to the murder of the latter soon after their return to Mooltan.

Detailed accounts of these tribes were given twenty years later by Leitner who succeeded in penetrating the Hunza-Nagir valleys in 1866. A large mass of information on the languages spoken in that area was brought back by him, and he was the first to point out the Aryan affinities of the Dardic language. Leitner also published anthropometric measurements of 12 men, one of whom, Jamshed, who belonged to the Kati tribe of the

Red Kaffirs was taken to England and measured by Dr. Beddoe. Drew, who for many years served under the Maharaja of Kashmir as a geologist and finally became the Governor of Ladakh, had an intimate acquaintance with the entire territory from Jammu to Gilgit and greatly added to our knowledge of the tribes inhabiting these regions by the valuable notes contained in his work on *Jammu and Cashmere territories* published in 1875. After Drew, the most important account on these tribes was by Biddulph, who was a member of the Forsyth Mission to Kashgar in 1873 and was stationed as Political Agent at Gilgit for several years. Like his predecessors however, his experience was mainly confined to the Burish and Dardic countries, and he had no first-hand acquaintance with Kaffiristan. The account given by him of the Siah-Posh tribes were derived from Kaffirs whom he met at Chitral, and other visitors to their country. Similarly Bellew's note on the Katis contained in his *Races of Afghanistan* (1880) was not derived from a visit to Kaffiristan, but was based on sources available at Kabul. The first European to enter Kaffiristan was Lockhart who entered the upper part of the Bashgul valley in 1885-86. It is to Robertson, however, who spent nearly a year (1889-90) in Kamdesh and other parts of Kaffiristan, that we owe all our hitherto available information regarding the habits and customs of the Red Kaffirs, specially the famous Kam tribe.

Systematic anthropological investigations in the North-western Himalayan regions commenced with Baron Mezö-Kovesd Ujfalvy's visit in 1881 under the auspices of the Société d' Anthropologie de Paris, in continuation of his earlier researches in the Pamirs and Russian Turkistan. Ujfalvy spent several months in Ladakh, Balti and Dardistans and published anthropometric measurements on their inhabitants. After him the next important work was that of Stein, who in the course of his three Archæological Expeditions to Central Asia during 1900–1928 measured a large number of tribes including Red Kaffirs, Khos and Hunza Burushos. In 1912, Dixon travelled through the Astor valley to Hunza-Nagir States on his way to Western Tibet and took measurements on a large number of the Burusho. In the following year, the Italian Expedition to the Karakoram ranges under de Filipi made a detailed survey of the somatic characters of six major racial groups of the Upper Indus valleys. Lastly in 1929, the author, as a member of the Scientific Expedition of the Government of India, which was sent to collaborate with Morgenstierne's linguistic survey of the Hindukush regions on behalf of the Norwegian Institute for Comparative Research in Human Culture, visited Chitral, and the Rambur and Bumboret valleys of Chitral Kaffiristan and carried out an extensive anthropological survey of the races living there.

Linguistically, the tribes living in this area have been classified under two heads, namely, Dardic and Burushaski, with

Kaffiri occupying an intermediate position between Iranian and Indian. Burushaski is spoken in Yasin and the Hunza-Nagir valleys, and as yet unaffiliated to languages of any known family, though attempts have recently been made by Bleichsteiner (*The Burushaski Language* by D. L. R. Lorimer, **1**, Preface, 1935, Oslo) to connect it with Caucasian languages. The Dardic group comprises Kashmiri, Shina, Kohistani, Khowar and Kalash ; and in Kaffiri are included Kati, Waigeli, Ashkun and Presun. Grierson is inclined to regard the Dardic languages as 'semi-Iranian' forming a link between the Iranian and Indian languages spoken on both sides of the Hindukush (*Linguistic Survey of India*, **1**, pt. 1, 108, 1927, Calcutta). The researches of Morgenstierne, however, have shown the essentially Indian character of Dardic languages, though, as is natural, in the isolation of the Hindukush region some of the common features of the Ancient Iranian and Indian languages have been preserved which are now lost on the Indian side. Neither is Kaffiri an exception, and though standing somewhat apart, it shows much closer affinities to Indian than Iranian languages, in morphology, phonetics and vocabulary, specially with neighbouring Kalash and Khowar; the last two forming a sort of connecting bridge between Kaffiri and the purely Indian languages (*Reports of Linguistic Missions to Afghanistan and North-western India*, 1926 and 1932, Oslo).

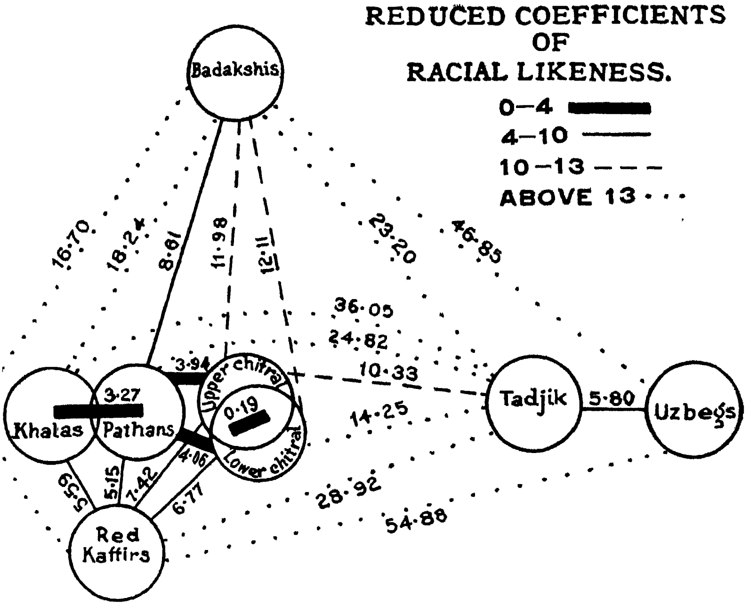

FIG. 1.

It will be well to keep this in mind in considering the racial characters of these tribes and treat the Western Group at first separately from the more Eastern one of the Upper Indus valleys. In Text-Fig. 1, I have reproduced the values of the Coefficient of Racial Likeness between these tribes. I am aware that Prof. R. Fisher (*Journ. Roy. Anthr. Inst.*, **66**, 57–63, 1936) has shown that the C.R.L. is not a measure of racial difference but a test of significance, and an unsatisfactory one at that. Nevertheless we may begin our discussion with these values without claiming anything more for them, than, that if they be not fortuitous due to the defects inherent in the method, they would give some indication as to the probability of their being random samples of the same population, *i.e.*, at their best they may be expected to tell us something of the probable alignments of these tribes.

According to these C.R.L. values therefore, there is a probability of the four Dardic tribes being random samples of the same population, but in the case of the Red Kaffirs the chances are somewhat less. With the extra-Indian groups, whether Iranian or Turkic, the chances are very little either with regard to the Dardic or the Kaffir, of belonging to the same population. Leaving them therefore aside, the results may be considered to accord on the whole with linguistic divisions, and *prima facie* there is nothing improbable about them. But beyond this chance membership of a common body we are told nothing about the racial character of that body—whether the somatic type is the same, or if there be more than one type, whether their distribution is uniform in the groups composing that body. For this, as well as for seeing how far the results obtained by the method of C.R.L. can receive independent corroborations we have to turn to the actual measurements and somatic observations for enlightenment. These may briefly be classed under four main heads, namely, stature, forms of the head and face, and pigmentation.

To take stature first, the differences between the mean values of the Kalash, Kho, Pathan and the Kashmiri are not significant, but the Kaffir appear to show significant differences from those of the first two, which may not be due to the errors of random sampling. If we examine closer, it is found that in the Kalash and the Kho the majority of the people vary from a short to medium stature, only 8 and 16 p.c. respectively in these two groups have a stature of over 1,700 mm., *i.e.*, tall. In the case of the Pathan of Dir Kohistan while the percentage of short people is about the same, that of the tall people increases to 22. Among the Red Kaffir, on the other hand, the percentage of short people is only 11 but that of the tall people is 28, *i.e.*, they have a much larger number of taller people among them. This becomes clearer when the Text-Fig. 2, showing the distribution of stature among these tribes is examined. Among the

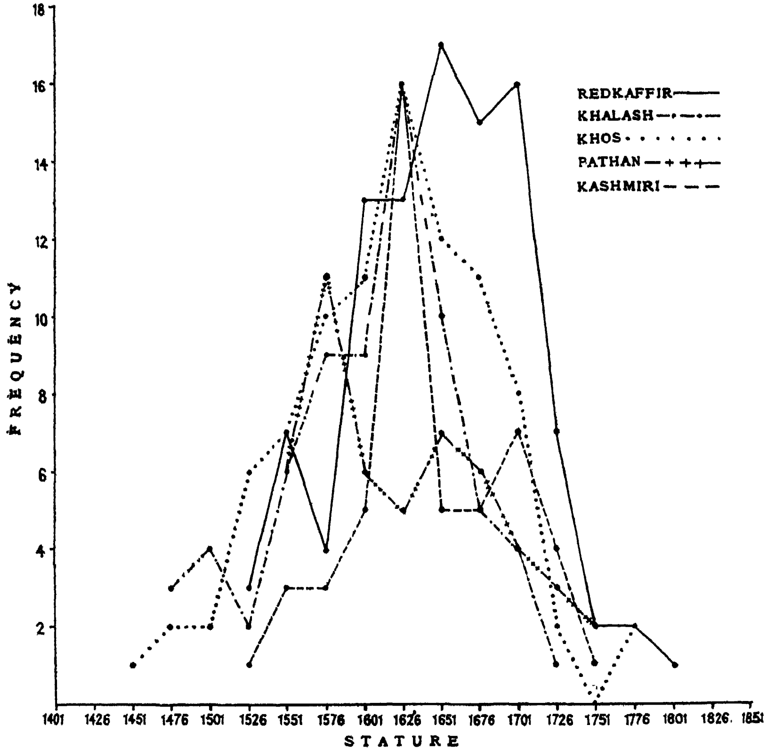

FIG. 2.

Red Kaffir, it would appear that the main range of variation is between 1,650–1,750 mm., while among the Kalash, Kho and Kashmiri it is only between 1,600–1,650 mm. The Pathans possess a predominantly short group, but they have, like the Kashmiri also a smaller number who are inclined to be tall. In other words the common factor among all these tribes is a short to medium statured people which is the dominant element among the Dardic tribes, but among the Kaffirs the tendency of the majority is towards tallness which is shared to a smaller extent by the Pathans of Dir Kohistan and the Kashmiris.

It is noticed (Text-Fig. 3) that in cephalic index the main body of the Kalash falls between 71–75, and among the Red Kaffir, Pathan and Kashmiri it is between 72–76, showing that though the Kalash have a relatively narrower head, all the four tribes are essentially dolichocephalic. On the other hand the Kho stand somewhat apart, and the distribution of the major type among them is between 76–80. There is also a small but perceptible number among them who are markedly brachy-

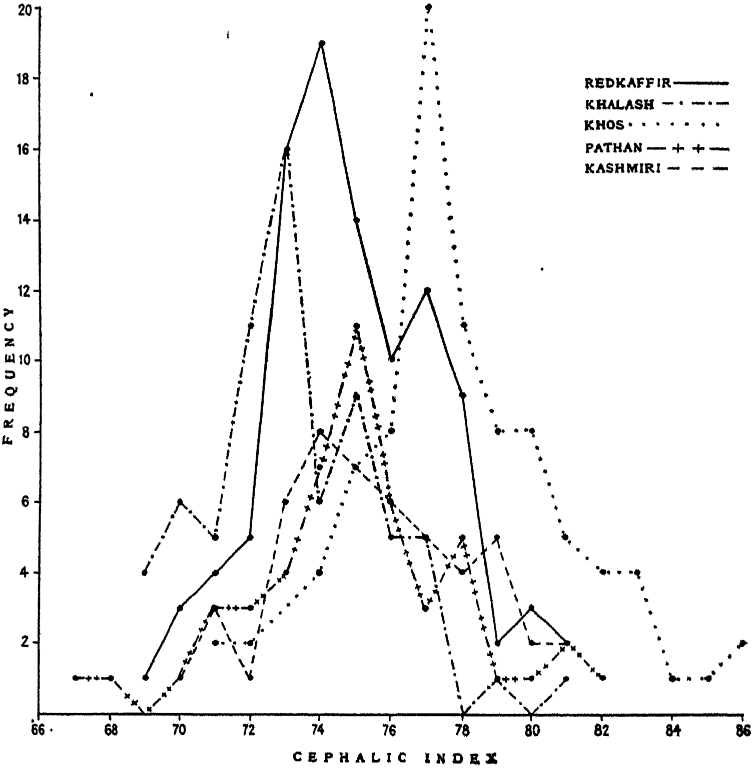

FIG. 3.

cephalic. It would appear, therefore, that the greatest common factor among all the groups is dolichocephaly, but the brachycephalic strain which has entered deeply in the Kho is present only to a small extent among the other four.

Turning to the shape of the face, the morphological height in all the groups is over 120 mm., but both the cheek bones and the lower jaw are moderately broad producing in many a pear and even a squarish type of face. In the majority, however, the facial form is longish and persons with a round face are very small. The difference in the shape of the face is not marked, though on the whole perhaps the Kalash and the Pathan possess a slightly longer face.

In Text-Fig. 4, is shown the distribution of the nasal index from which it will appear that the dominant elements in all the tribes lie between 60–70, with a small but an appreciable number of very narrow-nosed people specially among the Red Kaffir and the Kho.

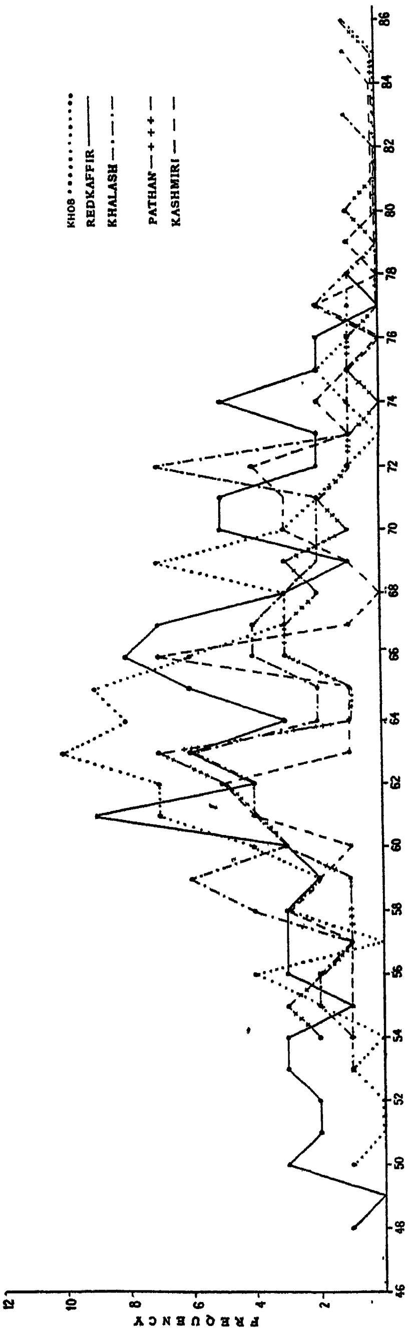
KHOS ••••••••••••
REDKAFFIR ———
KHALASH —·—·—
PATHAN —+ + + —
KASHMIRI — — — —
NASAL INDEX
FREQUENCY
46
48
50
52
54
56
58
60
62
64
66
68
70
72
74
76
78
80
82
84
86
2
4
6
8
10
12

FIG. 4.

There is also a fair number of people who discloses a mesorrhine index, but if the distribution curves be examined it will appear that the majority of these fall within 75, and may not be outside the range of the normal variations of the tribes. The number beyond this figure may perhaps with greater justification be regarded as due to a broader-nosed strain, more specially as among some of them the depression of the nasal root, and a rather broad flat nasal bridge were observed.

It is interesting to note that in all the four tribes by far the larger number of persons possesses a straight nose. The emphasis laid on hooked nose by Leitner, Biddulph, Ujfalvy and other previous writers, as a characteristic trait of the physiognomy of the people of this region has created the impression as if the prevailing type was so. The observations recorded by me, however, show that the percentage of men with the tip of nose slightly turned down does not exceed 27, and that of the truly hooked nose is not more than 16, in any of the tribe. If the two are combined, then the respective figures for the straight and convex noses would be as follows :—

	Pathan.	Red Kaffir.	Kalash.	Kho.
Straight nose ..	62	72	70	79
Convex nose ..	38	28	30	21

The dominant form among all the four groups would therefore appear to be a straight-nosed leptorrhiny. There is, however, a strain of aquiline-nosed people among both the Pathan and the Kaffir tribes which is slightly less marked among the Khos of the Chitral valley.

There is another character which requires some consideration, namely the form and shape of the eye. While there is no doubt that the vast majority among all the four groups have horizontal and open round eyes, there is a small percentage whose eyes are slanting and show distinct traces of the epicanthic fold. The figures for the four tribes are shown in the following table :—

Form of the Eye.

Tribe.	Round and horizontal.	Slanting.	Epicanthic fold.
Pathan	90	10	8
Red Kaffir	96	4	3
Kalash	93	7	6
Kho	86	14	8

It is interesting that a small proportion of people also show either complete absence or very slight development of hair on the lips and face. The Kalash disclose 8% of such people, the Kho 6%, the Red Kaffir 3% and the Pathan 2%.

Taking all these factors into consideration therefore, we may regard that among the Western group of tribes living in the valleys of the Hindukush mountains a small (1) Mongoloid strain is unmistakable. It is most noticeable among the Khos and is least marked in the Red Kaffirs. Flat, broad nose and short head, whose traces are present throughout in varying proportions, I attribute to this strain. It may also be one of the contributory factors to the lowering of the general stature of the population. The presence of a large proportion of short people must, however, be attributed to (2) another strain which seems to underlie the entire Himalayan population and was probably the primitive element, references to whose occupation of these valleys occur in the traditions of most of the present tribes. I agree with Prof. Fleure that this is a variant of what Eugen Fischer calls the Oriental type characterized by a long head and an aquiline nose. In addition, (3) it is clear that a tall long-headed strain with straight nose, and (4) another with medium stature, short head and a nose long but also inclined to be straight, must be distinguished. The latter is the Pamiric race of Ujfalvy and is undoubtedly a branch of what is commonly known as the Dinaric race of Eastern Europe. Frhr. von Eickstedt is undoubtedly right in thinking that this race forms the dominant element among the Khos of the Chitral Valley (*Man in India*, **6**, pp. 244-45, 1926).

The common elements underlying all the four tribes as disclosed by the values of the C.R.L., I attribute primarily as due to the second and third racial strains. The comparatively less close association of the Red Kaffirs with the other three groups appears to be due to the predominance of the tall long-headed strain among them which is not quite so marked in the latter. To this extent I think the values of the C.R.L. may be accepted as showing the correct alignment of these tribes, and not fortuitous.

Pigmentation.

Differences in the skin colour of the Hindukush tribes from those inhabiting the plains of India and the presence even of blond individuals among them, have been reported by travellers who visited these difficult valleys. Leitner, who published the measurements of two Red Kaffirs belonging to the Kati tribe, noted the ruddy skin colour and hazel eyes of the one and the reddish brown hair and hazel-grey eyes of the other (*Dardistan in 1866 and 1893*, App. 5, pp. 1–6). Similarly, Biddulph remarked (*op. cit.*, p. 128) that the complexion of the Siah Posh tribes, specially the Red Kaffirs of the Hindukush slopes, were very fair. Ujfalvy (*Les Aryens de l'Hindoukouch*, 1896) also spoke of blonds among the Khos of Chitral. Robertson, who had an intimate knowledge of Kaffiristan, observed light eyes and fair hair among Presun children, and considered that about 1% among the Red Kaffirs had red hair (*op. cit.*, p. 170). He was of the opinion however, that as a general rule the Kaffirs were less fair than the upper classes of Chitral (*op. cit.*, p. 169).

Systematic observations on the skin, eye and hair colours of these tribes were first taken by Stein (*Serindia 3*, *pp. 1387-88*, *1921*), who followed the instructions given in the *Notes and Queries on Anthropology*, but did not have any recognized chromatic scale to compare with. The records of his observations are given below :—

Skin colour.

Tribes.	Brown.	Yellowish brown.	Rosy white.
Kaffir	22	nil	78
Khos of Chitral	nil.	nil.	100
Khos of Mastuj	4	4 (?)	93

Hair colour.

Tribes.	Black.	Dark brown.	Fair and medium.
Kaffir	17	56	28
Khos of Chitral	5	91	5 (?)
Khos of Mastuj	14	82	4

Eye colour.

Tribes.	Dark (All shades of black and brown).	Medium (Hazel and green).	Light (All shades of blue and grey).
Kaffir	11	61	28
Khos of Chitral	..	91	9
Khos of Mastuj ..	14	79	7

According to these figures, therefore, the majority of people among all these tribes have a rosy-white skin colour, dark-brown hair and hazel or green eyes. There are in addition a distinctly blond element with blue and grey-blue eyes and medium to fair hair, and a dark one with brown complexion, black eyes and black hair. Among the Kaffirs both these two strains are well marked, but the Khos appear to be overwhelmingly of rosy-white skin colour, medium eyes and dark-brown hair.

The observations recorded by me on integumentary colours were obtained with the help of the standard scales of von Luschan, Martin and Fischer. As is well known, these scales are neither comprehensive nor quite satisfactory, specially the chromatic scale of von Luschan. Greatest care, however, was taken in matching the different shades in good daylight, and though some of them were approximations and not of exact correspondence, they have an advantage over visual impressions unchecked by any objective standard.

The results of these observations are summarized in the following tables :—

Skin colour.

Tribe.	Dark brown.	Brown.	Light brown.	Rosy white.	Sallow white.
Pathan	..	14	16	70	..
Kalash	..	6	10	74	10
Kho	..	5	..	93	3
Red Kaffir ..	2	19	11	63	5

Eye colour.

Tribe.	Black.	Dark brown.	Light brown.	Hazel and green.	Grey-blue and blue.
Pathan	18	44	18	8	12
Kalash	6	26	29	24	15
Kho	2	29	38	20	11
Red Kaffir ..	5	28	33	22	12

Hair colour.

Tribe.	Black.	Dark brown.	Light brown.	Fair.	Red.
Pathan	49	37	11	..	..
Kalash	53	17	12	..	..
Kho	23	43	32	2	1
Red Kaffir ..	51	7	11	18	1

Among the Red Kaffirs 12%, among the Kalash 18%, and among the Pathans 3% had grey hair.

It will be seen that while the above figures are in general agreement with the results obtained from Stein's observations regarding the occurrence of a dark, medium and a blond element among these people, the presence of a light-brown strain seems to have escaped his notice. The respective proportions between the various elements require also some modifications, specially his intermediate group of medium-eyed people for which he gives a very high percentage. It is possible that the light-brown and the hazel and greenish eyes were classed together in his medium group, and a sufficient distinction was not made between the light-brown and the truly blond hair. It should also be remembered that Stein's records were made on very small samples, namely 18 Kaffirs, 22 Khos of Chitral and 28 Khos of Mastuj against 100 Red Kaffirs, 90 Khos from Chitral and 150 Khos from Mastuj and upper Chitral observed by me. Percentages based on such small numbers, which can on no account be regarded as representative samples of the populations, are apt to be misleading and must always be taken with reserve.

If now these observations on integumentary colours are considered in the light of the metric data discussed above we may regard the brown strain as due to the Oriental race which seems to be at the basis of the population of the entire region. We have found this element to be strongest among the Pathans where also the darker strain predominates. To the Mongoloid race may probably have to be attributed the light yellowish brown tint in the skin colour and in part also to black hair and dark-brown colour of the iris found in many individuals. The lighter skin, eye, and hair colours appear unmistakably to be due to the rest of the two strains. As the truly blond with sallow white skin, grey-blue eyes and fair hair is comparatively more marked among the two Kaffir tribes, where also the tall long-headed element is conspicuous, the conclusion seems unavoidable that blondness is more associated with this race. A rosy-white skin colour with light-brown hair and medium eyes appears to be the characteristic of the Dinaric type which is dominant among the Khos of the Chitral valleys.

To turn to the Eastern group, the Burusho live in the extremely difficult rugged valleys formed by the western ranges of the Karakoram mountains, north of Gilgit, between Latitude N. 36°–37° 10′ and Longitude E. 74° 10′–75° 40′, in the States of Hunza, Nagir and Yasin, in the last of which a variant form of Burushaski known as the Werchikwar is spoken. The total number of the Burusho of the Hunza and Nagir valleys as recorded in the Census of 1931 is 20,813, and of the Werchikwar-speaking Yasinese 7,518, making a grand total of 28,331 persons (Lorimer, *op. cit.*, **1**, pp. 38–47).

Further south-east in the Upper Indus valleys live the Baltis, the Brokpas (the highlander section of the Baltis), the Machnopa and the Purigi. Of these the first and. the last are now Tibetanized in speech, but the Brokpas and the Machnopas still retain their Dardic languages.

Leitner (*op. cit.*, App. 5, pp. 1–7) was the first to publish measurements on the Burusho of which one was from the Hunza and five from the Nagir valleys. The Hunzukut was a dolicho and the others were mesocephals. They were of medium stature excepting Khudayar who was very tall (182 cm.) and had light eyes. The nose was usually straight,. but two had slightly aquiline noses. Dixon, who visited the Burushaski country in 1912, measured a series of 92 Burusho of the Hunza valley. Morant has recently published (*Journ. Roy. Anth. Inst.*, 66, 1936) statistical analysis of the measurements taken by Sir Aurel Stein on 95 men from the Hunza valley, but unfortunately the value of his constants has been marred by his inclusion of 20 Wakhis in his sample who penetrated in the Herber valley in recent years.

The measurements taken by Dainelli comprise 150 Baltis, 50 Brokpas, 50 Machnopas and 50 Purigis. In Text-Fig. 5 the values of the C.R.L. between the last four tribes are given. As in the case of the Western group, nothing more is claimed for these values than a possible indication of the true alignment of these tribes. If the figures shown be not fortuitous due to the inherent defects of the method, there is a probability of the first three constituting random samples of the same population.

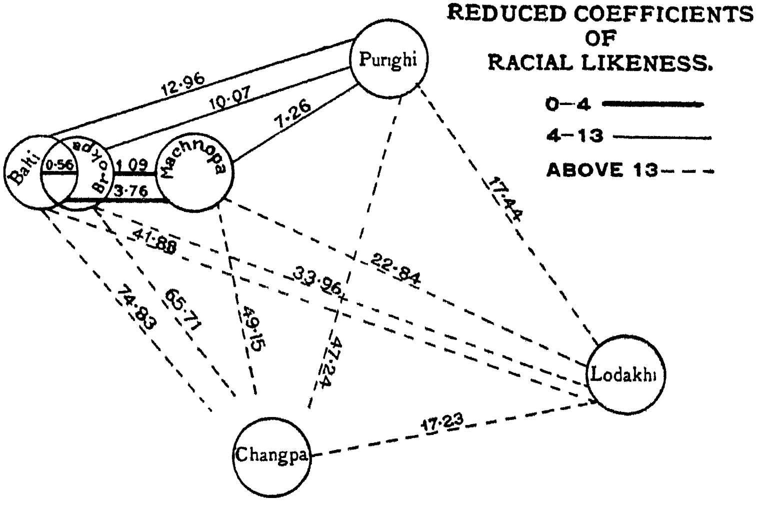

FIG. 5.

With the Purigi, however, the chances are somewhat less. Now if the individual characters are considered separately it would seem that so far as stature is concerned (Text-Fig. 6) the main

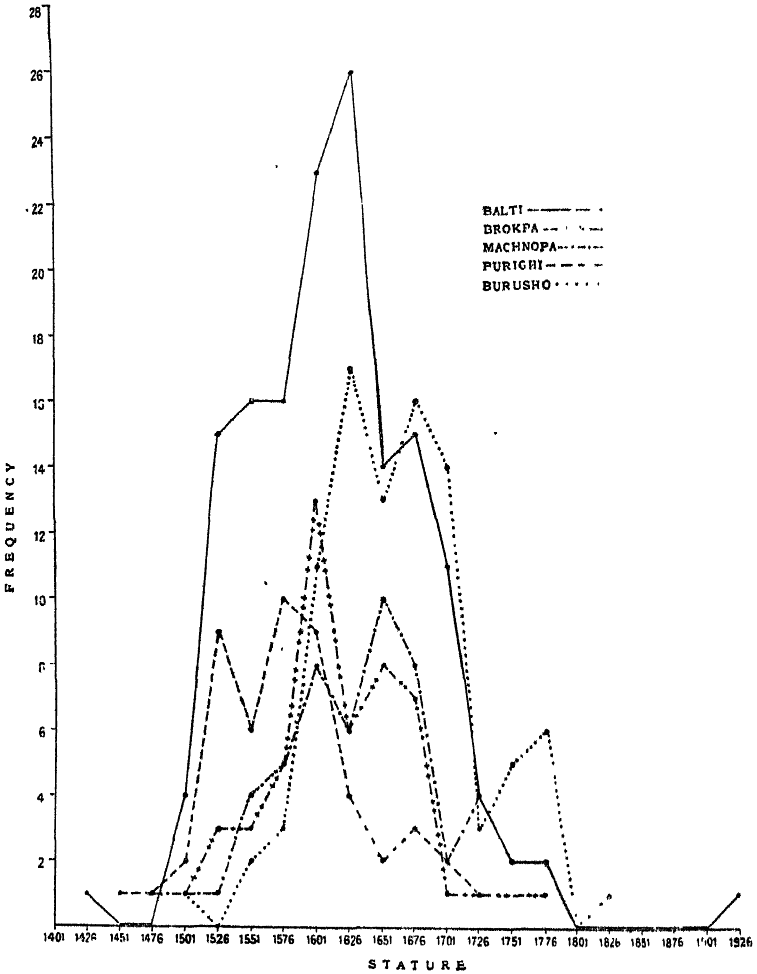

FIG. 6.

distribution of the Burusho lies between 1626–1701 mm., 35% of the people being tall. Among the Dardic group on the other hand, the main distribution lies between 1590–1690 mm. with a small proportion of the tall (the percentage not exceeding 14 in the case of the Brokpas) but a large percentage of the short.

Among the Purigi the percentage of the latter is as high as 58, in the Baltis 34, Machnopas 26 and in the Brokpas 22. In other words, the characteristic feature of the Dardic tribes, as was also noticed in the western section, is short to medium stature, the Burusho containing more of the taller element.

With regard to the head form, the mean value of the cephalic index of the 92 Burusho measured by Dixon is 77·45±·26 and that of the 75 measured by Stein is 79·3. Among Dixon's Burusho 35% were dolicho and only 14% brachycephalic. The main distribution, as shown in Text-Fig. 7, falls between 75–80.

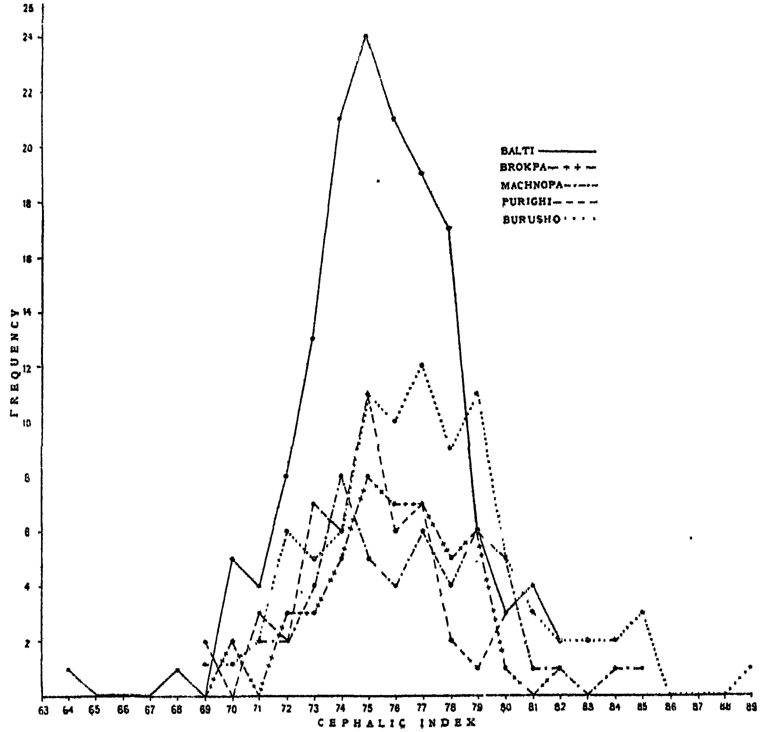

FIG. 7.

The mean cephalic index of the Baltis measured by Dainelli is 75·69, of the Brokpa 75·89, Machnopa 76·92 and Purigi 75·32. The main distribution of the Baltis falls between 74–78, that of the Brokpa 75–79, Machnopa 74–77 and Purigi 72–77. In all these tribes there is an appreciable element of hyperdolichocephals and the dominant type is dolichocephalic, the percentages being 64 for the Purigi, 52 for the Balti, 49 for the Brokpa and 42 for the Machnopa, among whom there is a small (8%) but distinctly brachycephalic strain. Compared to the Dardic tribes therefore, the Burusho are broader headed.

In Text-Fig. 8, I have represented the distribution of the nasal index of the 5 tribes from which it will appear that two distinct types are represented. The leptorrhine type is dominant among the Baltis, Brokpas and the Machnopas, but among the Purigi and the Burusho the prevailing type of nose is broader. The percentage of the platyrrhine, however, is very small, being only 8 among the Purigi and 12 among the Burusho. On analysing the nasal form it appears that the mesorrhinic index is not due to shorter nasal length but rather to a greater breadth. Among the Baltis, Brokpas and the Machnopa the mean nasal height exceeds 52 mm. and among the Burusho and the Purigi it is 51 mm. The mean nasal breadth, however, centres round 37 mm. in all the tribes.

To turn to the shape of the face, the mean morphological height is 118·06 among the Burusho, 117 among the Balti, 118 among the Brokpa, 117 among the Machnopa and 118 among the Purigi. It is therefore, considerably shorter than in any of the tribes belonging to the Western group, where the minimum mean height is never below 121 mm. Dainelli did not measure the bizygomatic diameter, but judging from his bimalar breadth the shape of the face does not appear to be longish but rather more like that of the pear.

Materials concerning the non-metric characters of these tribes are very scanty, but from figures published by Biasutti (*Spedizione Italiana De Filippi Nell' Himalaia, Caracorume Turchestan Cinese—1913-14, 9. 227–32*) it appears that supra-orbital ridges were marked in 78% among the Machnopa, 45% Brokpa, 40% Purigi and in only 20% Balti. In the rest they were either feeble or entirely absent. The nasal bridge is usually prominent but among 23·4% of the Balti, 12% Brokpa and 24% Purigi it tends to be flat.

The figures given for pilosity shows that in 21% of the Balti, 26% Brokpa, 18% Machnopa and 44% Purigi, facial hair is entirely absent, and among an equal proportion it is very moderate.

From all these considerations it would appear that the basic racial type is the same dolichocephalic strain with prominent long nose, which was found to be underlying the population of the Western valleys. Among the tribes of the Upper Indus valleys it is very much stronger, specially the Machnopa. There is no doubt that among the Burusho also this is the basic type. We may consider therefore, that this variant of the Oriental race is the dominant strain in the North-western Himalayas and may be regarded as the characteristic type of this region. There may also be a more primitive ancient layer of short-headed but mesorrhinic population as Biasutti thinks, but I am inclined to

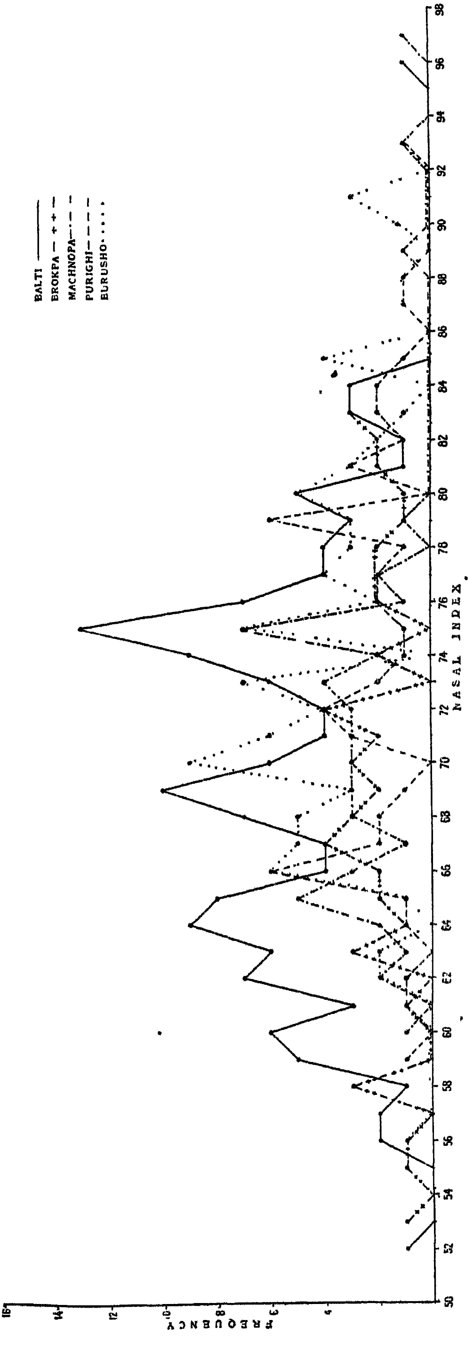
BALTI ——————
BROKPA — + + —
MACHNOPA—·—·
PURIGHI— — — —
BURUSHO·····
NASAL INDEX
FREQUENCY
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Fig. 8.

the view that the undoubted Mongoloid strain present in these tribes is responsible for mesorrhiny. Among the Western tribes it appears very probably to be the contributory cause, and if we consider in this connection the prevailing smoothness of the forehead and the scantiness or the entire absence of facial hair in a large portion of the population, it is difficult to doubt that the Mongoloid blood has entered considerably among the population. Attention has already been drawn to the fact that the increase in the nasal index observed among many of the individuals in these tribes is due not so much to the shortness of the nasal height as to the increase in the nasal breadth, a characteristic more observed among the Mongoloid races than others, and lends further weight to the view of the Mongoloid origin of mesorrhiny seen among an appreciable percentage of these tribes. The closeness of the C.R.L. values between the Dardic tribes therefore, is to be ascribed to the Oriental element which forms the underlying substratum among these tribes, and to this extent, the probability of all four of them being random samples of the same population may justly be recognized. In addition to these types the Dinaric strain is clearly visible among the Burusho and to a lesser extent among the Dardic tribes, specially the Machnopa. Finally the presence of the tall long-headed leptorrhine strain has also to be admitted, in particular among the upper classes though not in such a dominant form as among some of the Western tribes.

Pigmentation.

The skin colour in the Dardic group is in general light brown, but as Drew remarks, often light enough for the red to show through it (the *Jummo and the Kashmir Territories*, pp. 423-24, 1875). Rosy-white skin colour and hazel eyes are not infrequent and as Biasutti notes, among the Baltis and the Machnopas an appreciable percentage of people with medium eyes are observed. In one individual belonging to the latter tribe (No. 43 of the Dainelli's list) blue eyes and light chestnut hair was noticed (*op. cit.*, p. 191).

Among the Burusho the skin colour is lighter, and more like that of the Western tribes. As early as 1880, Biddulph remarked (*op. cit.*, p. 38) that the people in Hunza and Yasin had ruddy complexion and fair and even red hair was not uncommon. The presence of red-haired individuals among the Burusho was also noticed by Ujfalvy (*op. cit.*, 1896, pp. 258-59). Stein's records of the integumentary colours of the Burusho summarized by Morant (*op. cit.*, pp. 35-36) indicate that 94% of the people had rosy-white skin colour, 5% brown and only 1% yellowish tint. Among 35% of the people the colour of the eye was dark, in 50% medium and in 15% light. In 76% the hair was black but in 24% it was fair.

As in the case of the Western tribes, I would ascribe the darker element to the Oriental and the lighter medium strain to the Dinaric races. The truly fair or the blond element appears more probably to be due to the tall long-headed race as seen in the Kaffiri tribes.

From the foregoing review of the data available on the physical characters of the Hindukush tribes the basic racial strain appears to be a variant of the Oriental race described before. I was at one time inclined to accept Biasutti's suggestion of a more primitive layer of a short, long-headed mesorrhinic population, but a careful survey of the somatic traits of the Western tribes has convinced me that the cause of mesorrhiny is Mongoloid admixture. This seems also to be true in the Eastern valleys. The 'tipo-Dardo' of Biasutti and the 'Dardic type' of Ujfalvy 'with faces like birds of prey and aquiline noses' is not a separate strain but only an accentuated form of this basic type. The darker skin colour and black eye and hair are undoubtedly due to this race, though the Mongoloid strain which has certainly entered in the population may also be a contributory cause.

Besides this principal race we have in the North-western Himalayan region the southern extension of the Dinaric race. In its strongest form it is found among the Khos and the Burushos, but it occurs also among the Dardic tribes. If the records of the integumentary colours are considered it is difficult to escape from the conclusion that it is essentially a race with medium eyes and hair, but of light skin colour. The large percentage of such people among the Khos and the Burusho is largely due to this type.

It has undoubtedly spread from the Central Asiatic regions around the Taklamakan desert where its presence has been known from the earliest historical times, and among the tribes of the Pamirs it is found in its present form.

The third and the last racial strain is the tall dolichocephalic type with long but straight noses. There is no doubt that it forms a very important layer in the population of the entire region in both the Western and Eastern Dardic tribes. Its presence in the upper classes of the Burusho also is undoubted. Ariëns Kappers has shown (*An Introduction to the Anthropology of the Near East*, pp. 94–125, 1934) after a careful survey of the races of the Aral-Caspian regions that the characteristic of the Caspian or the tall, long-headed race is the clustering of the main peak around the values of 72–74 in the distribution curve of the Cephalic index. In the Kaffir tribes of the Hindukush, the Red Kaffir and the Kalash we notice the same tendency. In stature, nasal form and the shape of the face also it is similar to the Aral-Caspian type and closely related to the strain which forms the dominant element in the North European race. Distinction mainly lies in the integumentary colours. Whereas in Sweden the blond type represents 49% of the population and the brunette only 6%, the rest being intermediate, among the Kaffirs the former does not exceed 15%. The late Prof. Dixon, whose knowledge of the racial ethnology of the world has not been surpassed, was of the opinion that 'the original skin colour of this tall, long-headed race in the steppe region of Eur-Asia was probably fair with brown hair and hazel eyes but they had inherent in them a strong tendency towards blondness, which whenever the conditions favoured became more and more pronounced reaching its climax in the Baltic regions' (*The Racial History of Man*, p. 484, 1923). We know that pigment is caused by two or more pair of genes with at least one pair of genes for what are called colour activators. A deficiency mutation will suppress the appearance of pigment producing the condition known as blondness. It is certain that in this race, and as well as at least in another, namely the East-Baltic, this deficiency mutation must have occurred at some time or other. The association of fair skin with dark hair and eyes in the Oriental race, such as the Badakshis, and of hazel eyes with dark hair, would seem to show that the three are not linked characters, but that the deficiency mutations for skin, eye and the hair occurred separately. The mutation for depigmentation of the skin colour probably occurred first, then that of the eye and lastly that of the hair. In the Baltic tribes the high rate of the deficiency mutation probably accounts for the large percentage of the blond, but in the Western Himalayas the activators were probably dominant over suppression causing the general persistence of the more pigmented people.

Whatever the explanation be, the blond type is certainly to be attributed to the tall, long-headed race which has almost entirely been eliminated in the tropical plains of India where conditions did not favour its retention, though in the general structure of the head and the body, the Kaffiri are not different from the Punjabi, and the Punjabi from the North-European as Eugen Fischer recognized long ago.

In sum, we have three distinct strains in the racial composition of the Hindukush tribes, namely a dark Oriental type forming the basis, a short-headed intermediate, and a tall, long-headed fair race constituting the apex of the population with a certain amount of Mongoloid admixture specially in the Eastern section. The proportions of the three vary in different parts; those of the last two being stronger in the Western valleys whereas the basic Oriental and the Mongoloid being more conspicuous in the Eastern territories drained by the Upper Indus.

Whole Sugarcane plant in front of a Bamboo clump.

SECTION OF AGRICULTURE

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Presidential Address

HYBRIDIZATION IN AND WITH THE GENUS *SACCHARUM* (ITS SCIENTIFIC AND ECONOMIC ASPECTS)

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I. INTRODUCTION.

Artificial hybridization in the genus *Saccharum* has, in the past, been carried on mainly with the object of breeding improved types of sugarcanes for commercial use. Being generally propagated through vegetative means from cuttings the flower and the seed of the sugarcane received but scant attention till the possibility of employing sexual reproduction for breeding improved types was discovered. Since then, however, the raising of canes from seed has been widely resorted to in all sugarcane countries where the canes flower and set seed owing to the quick and tangible results therefrom.

The observations herein recorded are based on a quarter century of rather intensive cane breeding at Coimbatore employing literally hundreds of parents belonging to at least six different species of *Saccharum* and four genera—two of them widely separated from *Saccharum* in taxonomic position and morphological characters. The work at Coimbatore represents the first attempt in the sugarcane world at improving the subtropical types of canes and the parents employed for hybridization have had to be wider than in most other countries because of special features associated with the type of cane and growth conditions of the Indian sugarcane area.

II. THE GENUS *Saccharum.*

Taxonomic position.

Andropogoneæ.—Both according to Hackel (1887) and Bentham and Hooker (1883) the genus *Saccharum* is placed in the Tribe *Andropogoneæ.* Both these classifications are based mainly on morphological characters and though it is not definitely stated so, yet the *Andropogoneæ* would appear to have been considered to occupy a less primitive position than other tribes like the *Bambuseæ.* Recent taxonomic work on the grasses of the world by Bews (1929) and Hitchock (1935), based on both morphological and ecological characters, also places the tribe *Andropogoneæ* among the more evolved forms as compared to the primitive *Bambuseæ* and *Festuceæ.*

The tribe *Andropogoneæ* is confined almost entirely to tropical and sub-tropical regions and includes a large number of plants of economic importance such as the edible and fodder *Sorghums*, the Sugarcanes, various essential oil grasses like the *Cymbopogon* and *Vetiveria,* and certain thatching grasses.

Sacchárineæ.—The sub-tribe *Sacchárineæ* to which the genus *Saccharum* belongs is considered to be fairly primitive among the *Andropogoneæ* by Bews. Like many other genera the genus *Saccharum* has been occasionally revised, certain species being added to or taken away from it by various systematists. Dr. Jesweit (1927), for instance, took away *Saccharum arundinaceum* from the genus and placed it under *Erianthus.* At Kew, however, *Erianthus arundinaceous* still continues as *S. arundinaceum.*

Saccharum.—The genus *Saccharum* consists of erect perennial tall herbs with usually solid stems. The leaves vary both in length and in width, those of certain *S. spontaneums* consisting practically of the mid ribs alone. The greatest width of lamina is found in the cultivated forms of *S. officinarum* particularly in the thick class of sugarcanes where widths of over 3½ inches are found. The inflorescences consist of large terminal panicles of racemes often showy with the rhachis articulate and fragile; those of *S. spontaneum* are generally smaller than those of the cultivated species. Fairly detailed descriptions are available of the cultivated types of *Saccharum*, but these are often based only on the vegetative characters as the cultivated cane is generally propagated from stems or cuttings and the crop is cut without any reference to its flowering.

The genus is of economic importance as it includes the cultivated types of sugarcane which vary a great deal amongst themselves both in morphological characters and in the conditions under which they grow. It supplies an agreeable and important article of food and keeps going an important world industry.

The Wild Saccharum—habitat and range of forms.

There would appear to exist two different races of wild *Saccharums* both of which are confined practically to South-East Asia—India, Burma, the Islands of the Eastern Archipelago and New Guinea. Of these, the type represented by *S. robustum* was recently collected from the islands of New Guinea by Drs. Brandes and Jesweit (1928). Types of *S. spontaneum* have a much wider range being found from as far west as Central Turkestan and Afghanistan to as far east as Malenesia and the Tawaiian islands.

S. robustum.—The members of the *S. robustum* group have a family resemblance amongst themselves and are on the whole thicker stemmed and broader leafed than the *S. spontaneum* group. In breeding they have been found to possess a closer affinity with the 'noble' or thick class of canes. When crossed with 'noble' canes they yield hybrids of the same type; the type changes appreciably when the 'noble' canes are crossed with *S. spontaneum.*

The *S. spontaneum* group bears a close affinity to certain Indian canes, particularly *S. barberi.* The high juice qualities, however, of *S. barberi* at harvest—in contrast with the marked juice impurities associated with *S. spontaneum* and its progenies including hybrids—is perhaps indicative of a fairly wide intergeneric cross with *S. spontaneum* in the evolution of *S. barberi.* Results of intergeneric crosses to be referred to later in this paper support such a possibility; certain of the Sugarcane × Sorghum hybrids have shown very high juice qualities.

There exists a very wide range of forms in this group which differ widely in morphological, physiological and field characters as well as in sugar contents. Members of this group occur in the wild state throughout India and are found growing wild in places that are liable both to severe drought in summer and flooding during rains. They are at home on river banks and tank beds which dry up in summer.

The Cultivated Saccharum (Sugarcane)—distribution and types.

The sugarcanes in cultivation are divisible into two main groups, perhaps, originally derived from the two wild races previously mentioned, viz., *S. spontaneum* and *S. robustum.* The two types show in cultivation markedly different agricultural characteristics, the Indian indigenous canes related to *S. spontaneum* being on the whole hardier than the thick class of canes. On account of their comparative low yields and the fact that India does not figure in the sugar-markets of the world—not being an exporting country—the Indian canes were but little known, till recently, in sugarcane literature.

The Indian canes.—Unlike most types, denoted by the term 'sugarcane' as ordinarily understood in the sugar world, the Indian canes are mostly confined to the sub-tropical areas of India. Most of them are fairly resistant to violent changes in climatic conditions and some of them to frost as well. Growing as they do in sub-tropical India they get but a comparatively short period of growth—perhaps six months—being limited in the early stages by severe summer and in the later stages by frost.

One of the countries which is fairly similar to sub-tropical India in growth conditions is South Africa where also the 'Uba' cane very similar to one group of canes grown in North India—the Pansahi group—has been widely cultivated and is now getting replaced by certain Coimbatore productions. The severe growth conditions of sub-tropical India have established types which though poor in tonnage yet possess certain valuable characters such as hardiness and disease resistance. Java was the first country to utilize one of these types—Chan or Chunnee of the United Provinces—to breed canes resistant to 'sereh'.

'Noble' or Tropical canes.—The other group of cultivated canes is the one on which the sugar industries of the tropical world have been built. They are generally designated by the term 'noble' and, on the whole, are thicker stemmed and broader leafed than the first group. They generally need a longer period for full growth, show their best performance under tropical conditions and respond satisfactorily to good treatment. The record sugar yields in this crop have been from this class of canes. They are, however, less hardy than the first group, less tolerant to adverse conditions and generally more liable

to diseases. In the number of types in cultivation they are larger as, till the starting of the Coimbatore work, all intensive work on sugarcanes was confined practically to this class. The discovery of the viability of sugarcane seed—almost simultaneously in Java and Barbados in 1887-88—was from this type of canes. These are generally brighter coloured than the first group and are, on the whole, softer, more juicy, and possess less fibre; as a class they possess a shallower root system.

Species of Saccharum—their chief characteristics.

The genus *Saccharum* includes, beside others, six well defined species all closely related to the cultivated sugarcanes and with which they have been crossed as well. Their chief characteristics and distribution are given below :—

Saccharum spontaneum :—The types included in this species comprise a wide range of forms some of them inconspicuous plants with very narrow laminas to others growing to a height of 10 to 15 feet and not very dissimilar to the more primitive of the Indian canes. They are generally characterized by high fibre, markedly impure juices with very low sugar contents and ability to grow under extreme conditions including drought, water-logging, and frost. These are never cultivated for sugar. Types of this species occurring in India and the Eastern Archipelago have been studied in some detail at the Java and Coimbatore stations. The common Java type which is different from the main Coimbatore form in agricultural characters has been employed in the breeding of most of the recent popular Java canes and the mosaic resistance of some of them is attributed to this parentage. Similarly, one of the Coimbatore types enters into the parentage of all the Coimbatore seedlings found useful in cultivation.

The extent of variation in the forms of *S. spontaneum* in parts of India will be evident from the fact that a somewhat cursory collection of such types undertaken in a portion of Bihar in 1933-34 by R. Thomas yielded as many as eight distinct types differing in various morphological characters such as leaf width, stem thickness, size of plant and even depth and mode of branching of root system. In sugar contents they showed variation from 0·5 per cent. in juice to 17 per cent., the latter figure being higher than that of some of the Indian canes. The fact that such widely varying types exist in parts of India even to this day is perhaps indicative of certain of them being the primary centres (or centres of origin) for this species. The survey of *S. spontaneum* types in the country is being undertaken from Coimbatore as occasion permits, but there is little doubt that a well organized and thorough survey of such forms will yield very interesting results.

Saccharum barberi :—A group of canes rather similar to *S. spontaneum* in containing high fibre presence of the IV glume in the spikelets and ability to grow under comparatively unfavourable conditions has been placed in this species by Dr. Jesweit. They include a range of types not quite so wide as those included in the former species (*S. spontaneum*). The cultivation of this species for commercial sugar production is confined entirely to sub-tropical India and the species includes well known varieties like Katha and its allies in the Punjab, Chan or Chunnee and Saretha in the United Provinces and a few types of not much agricultural importance in Bihar.

Types of this species are found as far south as Madras being represented in Bombay by the variety Khalkya and in Madras by Hullu Kabbu. These canes arrow and set seed freely and possess an abundance of fertile pollen. The Chunnee used by Dr. Kobus of Java to breed 'sereh' resistant canes belongs to this species. This species and seedlings raised from them are prone to smut—a character which occasionally appears even in its hybrids. This is perhaps the most primitive of the Indian canes.

Saccharum sinense :—This includes a group of canes thicker and softer than *S. barberi* and does not at present possess much commercial value in India. It was partly used for chewing in sub-tropical India where it was liked for the purpose as being softer than canes of the *S. barberi* species. The canes of this species need more water, possess broader leaves than *S. barberi*, and are susceptible to both mosaic and red rot. They show distinctly higher glucose than *S. barberi*. These canes are related to the canes which were formerly cultivated in Japan and to the well known 'Uba' of Natal. In floral characteristics they resemble both *S. spontaneum* and *S. barberi* in possessing the IV glume, though there are differences in minor characters between them. They flower freely but do not develop fertile pollen.

It is possible that this species might have originated either in the Eastern parts of India or in countries further Eastwards.

The 'Mungo' and other canes :—Before passing to other species of *Saccharum*, mention needs to be made of certain groups of Indian canes that cannot be definitely placed in any of the above species.

Of such the most important is the 'Mungo' group of Dr. Barber which once had its representatives throughout the sub-tropical Indian belt from the Punjab in the west to as far east as Bengal. Though short in growth and of comparatively poor tonnage, it held till recently a dominant position on account of its excellent habit, high juice quality, uniformity of canes at harvest, and a general resistance to adverse conditions. These canes are typically short noded and in morphological and field characters suggest a distant resemblance to the 'Creole' cane. The chromosome number in the Creole is 81 (somatic) and in the Mungo group 82. Dr. Bremer has suggested that the Creole which is similar to the Indian cane Puri may be a hybrid between a member of the Mungo group and *S. officinarum*. These canes are generally late maturing.

They do not generally flower even under Coimbatore conditions where, very rarely, arrows half emerged from their sheaths occur perhaps once in a decade. They are also markedly defective in the floral organs. In the possession of ciliated lodicules they are nearer to *S. spontaneum* than either *S. barberi* or *S. sinense* though in general field characters *S. barberi* is nearer to *S. spontaneum*. The floral parts show certain rather primitive characters and it is possible that further work might indicate this to have been a fairly ancient group of canes in India. Certain of the varieties in this group show an awned IV glume, one of the characteristics of the Sugarcane × Sorghum hybrids. The white sugar industry of Bihar—once almost the only such industry in India—was for a long time dependent upon this group of canes. These canes stand out as a distinct class but have not received sufficient attention because of their non-arrowing.

A second group of such canes is that represented by the 'Nargori' group of Dr. Barber. Most of these are fairly resistant to water-logging and possess a markedly erect habit with prominent swollen nodes. This group is confined practically to water-logged areas in Bihar, but is steadily losing hold on cultivation from the easy superiority of recent introductions. These varieties do not flower generally and even if they do, are defective in sexual organs. It has not, therefore, been possible to employ this group in sugarcane breeding.

There is a third group—the Sunnaballe group of Dr. Barber—the members of which are found in cultivation throughout India. These are represented by Dhaulu in the Punjab, Khadya in Bombay, Nanal in Madras and Majora and a few others in Assam. This group of canes is often liked for its satisfactory juice qualities and the erect habit of growth. These canes also do not generally flower and have, therefore, not been used in breeding. They are liable to smut and are fairly hardrinded as well.

The canes above mentioned—while perhaps allied to *S. spontaneum*, *S. barberi* and *S. sinense* in some respects—are not definitely placeable in any of the above because of certain important differences in vegetative and field characters. While it is not possible to trace their origin with much definiteness, there is every possibility that they may have originated from the above species of *Saccharum* by natural hybridization either between themselves or perhaps even with other genera. The results of certain recent hybridization at Coimbatore indicate a distinct possibility of other genera also being involved. It is worthy of note that the above three groups do not generally flower and, even if they do, are defective in sexual organs.

Saccharum robustum :—This species is of recent discovery being a collection from the islands of New Guinea by Drs. Brandes and Jesweit and has not yet been fully described. It is very similar to *S. officinarum* in morphological characters and has been found useful both in Australia and in Hawaii for breeding seedlings of the thick or noble type. It resembles *S. officinarum* in the glabrousness of the main rhachis of the inflorescence and the absence of the IV glume.

Saccharum officinarum :—This includes at present, at any rate, all the cultivated canes of the tropical world. This species has been exploited to the fullest extent—both by raising canes from seed and by hybridization—to secure better commercial types for cultivation. In recent years this species has been widely crossed with others, particularly *S. spontaneum, S. barberi,* and *S. robustum* with the result that it is not fair to place the newer commercial canes under this species.

The varieties in this species are generally confined to the tropics, are thicker than the species enumerated above and, on the whole, are more susceptible to adverse conditions, diseases and pests. The glabrousness of the main rhachis and the absence of the IV glume separates it from *S. spontaneum, S. barberi,* and *S. sinense* and renders it akin to *S. robustum.*

Saccharum arundinaceum :—This species was for a long time under *Saccharum,* but was recently placed under *Erianthus* by Dr. Jesweit on account of its distinctly shorter callous hairs (shorter than the spikelets), the absence of defined transverse marks in the leaf, and the marked felt of hairs at the base of the lamina inside and above the ligule. To this might be added another distinct character, viz., that the root eyes on the stem are generally in one single row in *S. arundinaceum* unlike the 3 to 6 rows of the other species of *Saccharum.*

This species is often grown as a hedge plant round betel leaf gardens in South India. It has practically no sugar, arrows fairly freely and has been crossed with *S. officinarum.* If it is a *Saccharum,* it is perhaps the largest form being larger than *S. robustum* under Coimbatore conditions. Unlike most cultivated species of *Saccharum* in which the canes die out each season, they have been known to live for over two years in this species.

III. INHERITANCE IN *Saccharum.*

Variation.

One of the facts first noticed after the discovery of the viability of the sugarcane seed was the very wide range of forms resulting from the same parent even when the needed precautions are taken against cross pollination with other varieties. The explanation for such behaviour is the heterozygous nature of the parents and the fact that most sugarcanes in cultivation are polyploids—the species *S. officinarum* being octoploid. The economic results resulting from the raising of seed canes have been so pronounced and the needs of the sugar industry so urgent and insistent that most sugarcane breeding stations have gone in largely for economic results unmindful of the scientific explanations behind the production of these types.

Nor can I visualize in the near future a time when such work will be taken up as a main item in the sugarcane stations of the world. The problems associated with the inheritance of characters in sugarcane would fit in better with the atmosphere of universities engaged in work of academic nature or as but side lines in the existing breeding stations. Such work is likely to be long in duration but there is little doubt that ultimately it will be needed to place sugarcane breeding in line with that of other crops. It may perhaps receive due attention when the economic results that now follow from cane breedig become scarce and work of the fundamental nature is indicated. The extent of variation will be apparent from the fact that a population of over 2,000 seedlings from practically selfed flowers of a striped cane at Coimbatore did not reveal any two which were even similar when examined in some detail. In spite of this wide variation, however, there is evident a kind of family resemblance in seedlings raised from the same species or even variety, indicating that characters are inherited in the sugarcanes, though their nature is veiled and modified by other factors.

In-breeding.

As compared with most other crops there has been very little 'in-breeding' in the sugarcane and this for a variety of reasons. Firstly, the sugarcane plant is grown for its vegetative part which is milled for sugar production. As it is also propagated by vegetative means in ordinary cultivation the inflorescence is only an incidence of minor importance in the growing of sugarcanes. Secondly, the wide variation that is observed in seedlings from seeds of even the same inflorescence has naturally made sugarcane breeders averse to propagate their material from seed. Thirdly, in the absence of any apparent laws governing inheritance it does seem unprofitable to self each individual of such large populations as are usual in sugarcane breeding.

The opinion has been held in certain quarters that even in sugarcanes in-breeding is worth attempting either to eliminate undesirable characters or in the interests of science. At present, however, the breeding of improved types by a suitable combination of various parents is so much quicker in economical results that in-breeding is not likely to be taken up in the near future for this purpose. In fact, recently the Experiment Station in Hawaii indulged in a somewhat unique experiment by planting in close proximity to one another different canes from all parts of the world—India, China, Australia, Java, New Guinea and the islands of the South Seas—with the deliberate intention of working into the parentage as many canes as possible. In such a medley of varieties all arrowing together there was every possibility, as it was deliberately intended, of pollen from different cane varieties settling on the same mother arrow and even on the same stigmas.

There have been certain rather interesting examples of 'in-breeding' at Coimbatore. One such was the raising of seedlings on a large scale from practically selfed arrows of canes belonging to the species *S. barberi.* It was found that none of the productions were real improvements on the parents and, barring one out of 1,800, the seedlings were inferior to the parents in growth vigour. A hybrid between the noble cane Vellai and the Coimbatore *S. spontaneum* was selfed for two generations without obtaining canes superior to the F_1 hybrid in field characters, but there was a distinct improvement in sugar content when the selection from each generation was made on this basis. There was a third instance of continuous in-breeding at Coimbatore and this was from a hybrid which was originally obtained through a rather complicated crossing between a Mauritius cane, an Indian indigenous cane (*S. barberi*) and *S. spontaneum.* Selfed for one generation a type was obtained which, though inferior to the original parent in vegetative vigour, proved distinctly superior to it in both early maturity and high juice quality, two characters for which the original cane was selected.

The above are indicative of the possible utilities of 'in-breeding' in the sugarcane. On Coimbatore experience its chief value is likely to be in accentuating certain characters in the new productions. The loss of vegetative vigour that is often associated with it would necessitate a futher hybridization with suitable types to improve the growth vigour.

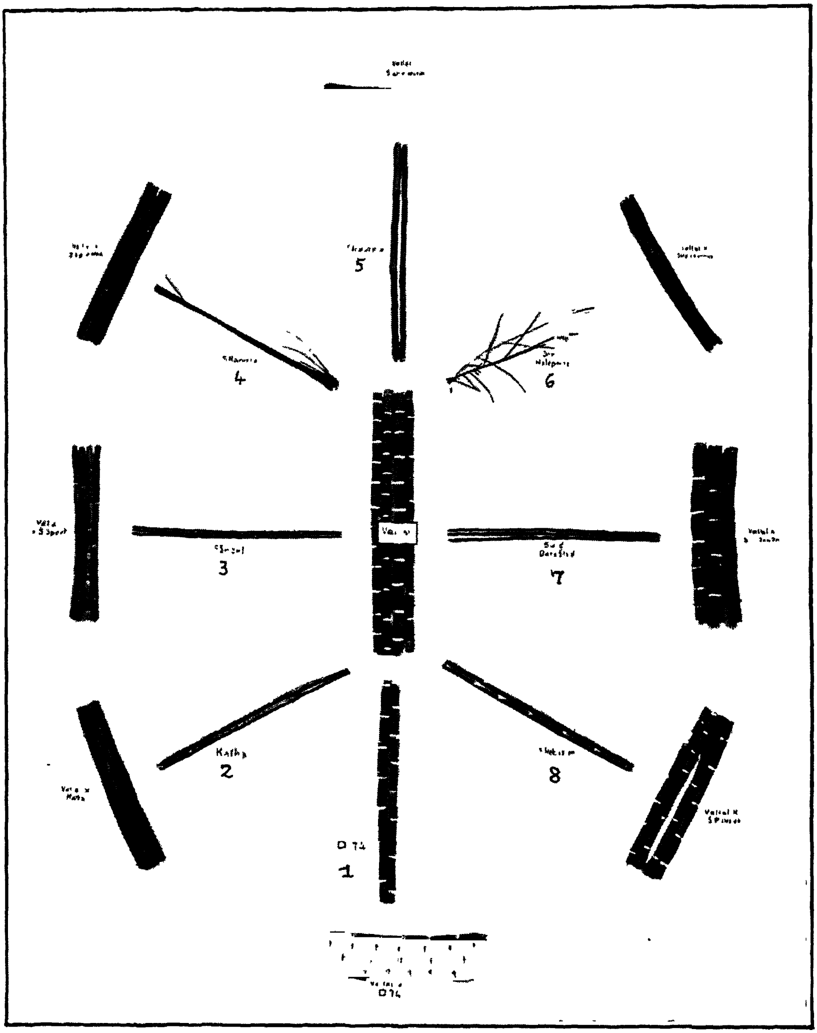
IV. HYBRIDIZATION IN *Saccharum.*

The results from 'in-breeding' proving so limited there is little wonder that most sugarcane breeding stations of the world turned their attention to hybridization between varieties, between species, and even between genera for obtaining economic results. This has rendered available for study large numbers of hybrids of fairly complicated ancestry, sometimes involving three different species of *Saccharum.*

Defective material.

The available material is, however, defective in the undermentioned respects. On account of the smallness and delicacy

PLATE 4.



The genus *Saccharum* has been widely crossed resulting in different types of hybrids. It has been crossed with

(1) S. officinarum,
(2) S. barberi,
(3) S. spontaneum,
(4) S. narenga,
(5) S. arundinaceum,
(6) S. halepense,
(7) Sorghum Durra stapf
(8) S. robustum,
(9) Bambusa arundinacea Willd.

of the floral structures in the sugarcane and the inhibitory effect of bagging on seed setting both emasculation and selfing have been but little practised in the breeding of commercial types. As a result of this, while the mother parent is known, the pollinating parent is often not so certain as there often exists the possibility of other unintended pollen reaching the stigmas. As the propagation of sugarcanes in cultivation is through vegetative methods the breeder is often liable to fasten his whole attention on the commercially useful types with the result that generally there has been no serious attempt at a study of the whole population resulting from a combination. All the seedlings of the F_1 generation do not flower and, even if they do, are sometimes defective in one or the other of the sexual organs.

Though thus the material does not often lend itself to accurate conclusions, yet it is generally capable of yielding very useful indications in the matter of inheritance. While all the seedlings of an F_1 generation may not be from the parents employed, yet the bulk of them are.

V. INTERVARIETAL HYBRIDS.

Hybridization between different varieties belonging to the same species has been more or less confined to *S. officinarum.* The largest amount of work in this line with useful results has been from tropical countries like Java, Hawaii, Mauritius, and the West Indian islands Barbados, Porto Rico and others. Such hybridization yields seedlings of the same class as *S. officinarum* but with useful differences in the matter of field characters which render them superior to existing types.

Intervarietal hybridization in *S. barberi* was not seriously attempted because of the poor class of seedlings resulting from this group when selfed. The *S. sinense* group does not lend itself to such work because of the defective floral organs in that species. The Mungo, Sunnaballe and Nargori groups of canes either do not flower or are highly defective in the floral organs and so such work is ruled out in these canes.

A fair amount of work on intervarietal crossing in *S. spontaneum* is in progress at Coimbatore with the main object of understanding the cytogenetic composition of the genus *Saccharum.* Intervarietal crossing in the other species has not been much in vogue.

VI. INTERSPECIFIC HYBRIDS.

Interspecific hybridization in the genus *Saccharum* started in Java for producing disease resistant canes. Coimbatore had to take this line of hybridization practically from its inception in 1912 as it was found that breeding inside the species, be it *S.officinarum* or *S. barberi,* did not yield suitable types for the main sugarcane belt of India situated in the Sub-tropics. It was early found at Coimbatore that even interspecific hybridization between *S. officinarum* and *S. barberi* (the indigenous canes of India) did not yield the desired result.

Faced with such a situation and the need for quick results, Coimbatore turned its attention very early to the raising of interspecific hybrids between *S. officinarum* and *S. spontaneum* (the Coimbatore form) and it is a record in sugarcane breeding that among the first forty seedlings of such hybridization (Vellai × *S. spontaneum*) a seedling of commercial value (Co. 205) should have been obtained. The success of this hybrid was a definite and clear indication of the somewhat extremely unfavourable conditions obtaining in parts of the Indian sugarcane area and there was no further hesitation at Coimbatore to utilize *S. spontaneum* in its breeding programme and the subsequent seedlings now popular in India have in their ancestry *S. spontaneum* suitably blended with both *S. officinarum* and *S. barberi*.

In interspecific hybridization with *S. spontaneum* as one of the parents—and it is generally the pollinating parent—the F_1 generation shows a general dominance of *S. spontaneum* characters which exhibit themselves particularly in growth vigour, hardiness, and resistance to adverse conditions. In hybrids with *S. officinarum* the *S. spontaneum* blood is often traceable in the presence of the IV glume in the spikelets. The F_1 generation shows obvious *S. spontaneum* field characters even when the intergeneric hybrids between *Saccharum* and *Sorghum* are crossed with *S. spontaneum*. As a parent, *S. spontaneum* introduces marked impurities in the juice and it is for this reason that such hybrids need further crossing with *S. officinarum*—what is termed 'nobilization' by the Java breeders—to ultimately secure the economic types.

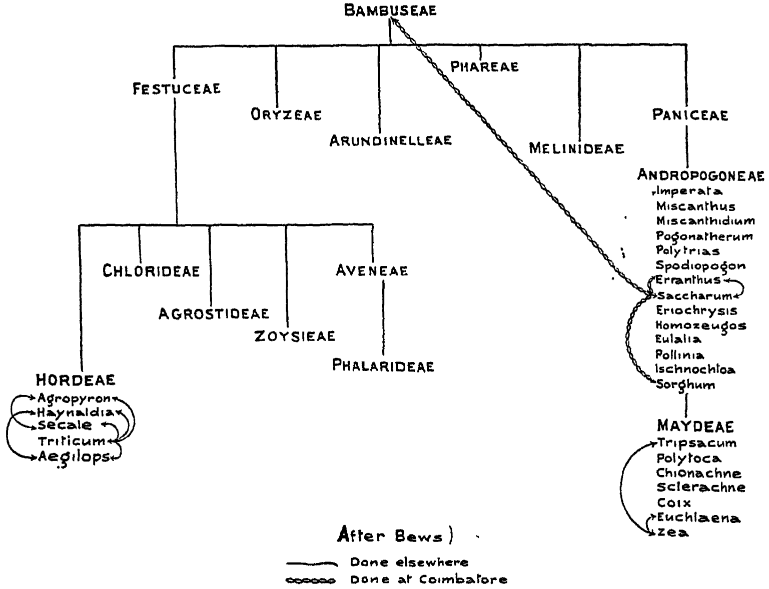
S. robustum has been known to introduce greater vigour of growth when crossed with *S. officinarum*. *S. arundinaceum* is a perennial as grown in South India and one hybrid raised with *S. officinarum* as mother is showing the perennial character in the hybrid.

The sugarcane world is taking more and more to such interspecific hybrids bringing into the parentage different species of wild *Saccharum* and this has been fully justified. Both Java and Coimbatore have materially benefited from the use of *S. spontaneum* and Hawaii and Australia are now using *S. robustum* for a similar purpose and for breeding hardier seedling canes for tropical regions.

VII. INTERGENERIC HYBRIDS.

The disparity in morphological characters and distance in taxonomic position between *Saccharum* and the genera with

INTERGENERIC HYBRIDS WITH *Saccharum.*



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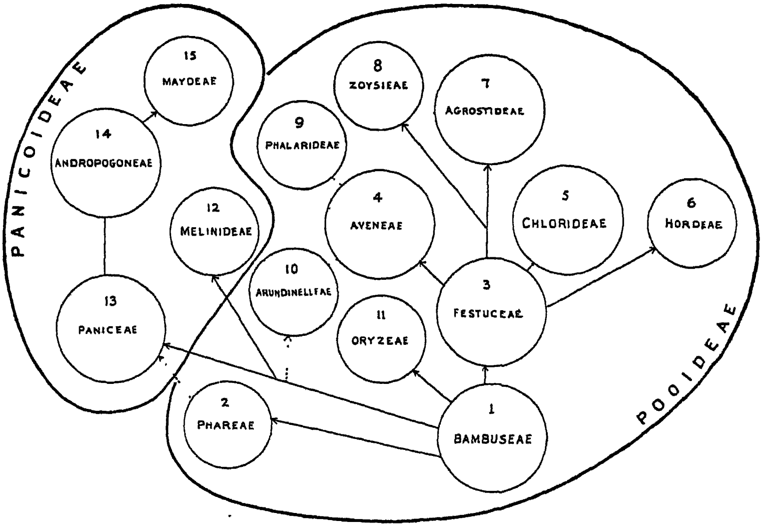


(After Bews)

The disparity in morphological characters and distance in taxonomic position between *Saccharum* and the genera with which it has been crossed is greater than in the case of the other intergeneric hybrids recorded hitherto.

which it has been crossed is greater than in the case of the other intergeneric hybrids recorded hitherto. It has been possible to cross *Saccharum* not only with other genera like Narenga (Narenga narenga), *Erianthus* (*Erianthus sara*) and *Sorghum* (*S. Durra stapf. S. halepense, S. sudanense, S. guineese*) but also with a genus belonging to a different sub-family *Bambusa*. Besides these, there are two other genera with which it would appear possible that *Saccharum* has been successfully crossed at Coimbatore. Further evidence is awaited before making definite announcements about them.

Hybrids with Sorghum and Bamboo.

The two intergeneric hybrids recently produced at Coimbatore—viz. with *Sorghum* and *Bambusa*—were effected with the definite object of securing a wide range of variation in the F_1 and introducing, if possible, new characters that might be useful in the further evolution of economic sugarcane seedlings. The *Sorghum* cross was made to introduce a shorter life cycle than that in the sugarcane which occupies the land from 12 to even 24 months. *Sorghum* is a 4 to 6 months crop. Sugarcane types maturing in about 7 months from time of planting have been obtained. Some of these have shown high quality juices in spite of the *Sorghum* parentage and, what is more important from the agricultural view point, they are further showing ability to stand in the field without appreciable deterioration for fairly long periods after attaining maturity, in some cases even to as long as 4 months. The economic types secured from this hybridization have, however, been disappointing in their growth vigour.

Hybridization with the bamboo was attempted to introduce greater vigour, if possible, not only in the interspecific *Saccharum* hybrids but also in the comparatively early maturing Sugarcane × Sorghum hybrids. Bamboo hybridization was successfully done only in December 1936 and the first batch have not yet finished their full year life cycle. They are showing satisfactory growth vigour but it is too early to predict the possible economic results.

Dominance of Saccharum characters.

The intergeneric hybrids above mentioned have shown some rather interesting phenomena with regard to the manner in which the characters are shown in the F_1 generation and transmitted in further back crosses with either parent. In both the *Sorghum* and Bamboo hybrids with sugarcane, the one fact that stands out prominently is the general dominance of *Saccharum* characters in the F_1. This is of great practical value to the sugarcane breeder who multiplies his improved canes by vegetative means. In the case of *Saccharum-Sorghum* hybrids the general dominance of *Saccharum* characters was found to persist even after twice back crossing the hybrids with their *Sorghum* parent.

Appearance of new characters.

Certain of the *Sorghum* hybrids exhibit characters not found in either parent; some of them carry leaves much thicker than either the sugarcane or the *Sorghum* parent and reminding one of the fleshy leaves of Crinum. Such characters get emphasized in further back crosses with *Sorghum*. Both the intergeneric hybrids above mentioned have also shown a very large number of abnormalities in stem, bud, leaf and the floral organs such as distorted, flattened or abnormal stems, double and multiple buds, partial suppression of lamina, forked leaves, multiple ovaries and multiple stigmas.

The *Saccharum-Sorghum* hybrids were mostly infertile in their first generation. On further vegetative propagation, however, some of them are showing an increasing fertility in the sexual organs with the result that, whereas in the earlier years no seeds could be obtained from them, it has since been possible to raise seedlings in large numbers from some of them and also back cross them with the two parents.

VIII. PECULIARITIES OF *Saccharum* HYBRIDS.

Distribution of parental characters.

As already mentioned, the first characteristic noticed in the growing of sugarcane from seed is the very wide variation even in selfed seedlings in all characters, the root system, the stem, the leaf and its appendages and in sugar contents, the character for which this genus is cultivated.

This variation shows itself in a rather interesting manner in the F_1 hybrids. Taking as an example, the intergeneric hybrids between the sugarcane (P.O.J. 213) and the bamboo (*B. arundinacea*), the bamboo characters are found distributed in the various F_1 plants. Certain of them, for instance, show the early branching (characteristic of the bamboo), others the central cavity in the stem, yet others the ascending root eyes of the bamboo and so on. It has to be remembered that this behaviour has a very important bearing on the production of useful sugarcane types through hybridization. When this hybridization was first announced, one of the fears repeatedly expressed was that the hybrids may prove as hard as the bamboo and hence difficult to crush. The behaviour above described would ensure that, even if the extreme rind hardness of the bamboo is inherited, it is likely to show itself only in certain of the hybrids. If, therefore, the F_1 generation is raised in large numbers there is every chance of getting some without the bamboo hardness. The vegetative propagation in the present case would again ensure that the bamboo hardness does not appear in the subsequent crop.

Difficulty to repeat types.

The second characteristic is the difficulty experienced in resynthesizing or rebuilding an improved cane that has once been obtained. This is deduceable from the variation already mentioned, but is perhaps worth illustrating in some detail.

During the season 1916 forty plants of the F_1 generation (Vellai × *S. spontaneum*) yielded in Co. 205 a cane of commercial value which it was possible to put straight into cultivation. This identical cross was repeated for at least four years and many thousands of seedlings of F_1 generation raised without being able either to reproduce or improve on Co. 205. Not only that; this F_1 hybrid was selfed for two successive generations and again many seedlings raised without being able to reproduce or improve upon the cane. A cane of the same type, but easily superior to it in many respects, was, however, secured in a somewhat roundabout way and by a complicated hybridization involving two canes of the thick or noble type and twice using *Saccharum spontaneum*. This is mentioned as illustrative of the large amount of chance or, as it has been called, the 'hit and miss' that is associated with the securing of results in sugarcane breeding.

Absence of segregation.

A third characteristic is the general absence of well-defined segregation of characters in *Saccharum* hybrids. This is attributed to certain unusual phenomena connected with the division and pairing of chromosomes yielding what are termed 'amphidiploids' or 'constant hybrids'. Even after carrying the process to more than three generations, types resembling the original parents have not been obtained.

Hybrid fertility.

Yet another peculiar characteristic of sugarcane hybrids is the absence of sterility among most interspecific hybrids. Even in the case of intergeneric hybrids it has been found that though the F_1 plants do exhibit sterility in the first year some of them produce fertile pollen after further vegetative propagation from cuttings and set seed freely.

Chromosome behaviour.

Fifthly, the chromosome behaviour in *Saccharum* presents certain rather unusual features. Dr. G. Bremer of Java was the first to work out the cytology of the sugarcanes. With funds from the Imperial Council of Agricultural Research, somewhat intensive work on the subject has been in progress at Coimbatore under a special officer, Dr. E. K. Janaki Ammal, for the last three years. Properly controlled crosses have been made and are being studied and various interesting features associated with meiosis in the *Saccharum* are revealing themselves. This work is throwing light on the origin and distribution of *S. spontaneum* types, the probable origin of certain Indian canes and similar problems. The large numbers associated with *Saccharum* chromosomes—particularly in the later seedlings—render the work both difficult and time consuming. A fund of knowledge is waiting to be revealed when, besides the number, the study of chromosome morphology advances further than at present.

IX. ECONOMIC AND OTHER RESULTS.

There can be little doubt about the material benefits derived by the Sugar Industry of the world from hybridization in the genus *Saccharum,* both intervarietal and interspecific. The wide variations found in seedlings from the same parent—which are accentuated by hybridization—has supplied the Sugarcane Breeder with large numbers of new types. This has rendered the elimination and selection from such a variety of forms the prime work of the Sugarcane Breeder, once an F_1 generation from the mating of judiciously chosen parents has been secured.

The possibility of vegetative propagation of the improved types, which ensures the continuance in the subsequent crops of the characters for which the new cane was first selected, has been a great asset in securing quick results. Another asset of great importance and utility to the Cane Breeder is the free hybridization between the cultivated and wild types of *Saccharum.* All agriculture involves the growing of a single species or variety close together on a given piece of agricultural land which is somewhat unnatural. This introduces a general weakening of the plant resulting in the greater incidence of diseases and pests among other evils. The introduction of the wild species into the parentage has been useful in overcoming somewhat the disadvantages resulting from the above mentioned feature of agriculture. It is significant that such hybridization has, in the past, been of great value in introducing into the new productions both hardiness and resistance to diseases and other adverse conditions. Work on similar lines in the case of other crops wherever possible is one of the lessons of *Saccharum* to the other crop breeders.

The wide disparities that have been bridged by the intergeneric hybrids with *Saccharum* give food for thought and stimulus for further research. It may lead to a new orientation in the concept of *genus* and *species* at least in the genera and families allied to *Saccharum.* It engenders the feeling that, while perhaps a great deal has been done in plant classification, further new light may yet be in store for the patient Researcher who can both describe his plants and also suitably hybridize them with one another.

SECTION OF MEDICAL RESEARCH

President :—Sir U. N. Brahmachari, Kt., M.A., M.D., Ph.D., F.N.I., F.R.A.S.B.

Presidential Address

THE CONQUEST OF KALA-AZAR AND CERTAIN OBSERVATIONS ON THE CHEMOTHERAPY OF MALARIA.

Ladies and Gentlemen,

We are meeting under the most tragic circumstances. The sudden death of Lord Rutherford who was to be our General President has cast the deepest gloom over our Congress. The world has lost in him one of its most distinguished scientists who smashed the atoms, and though he breathes no more, his discoveries may one day enable one to travel to that mysterious region among the atoms and molecules wherein enters the breath of life. We express our deepest sense of sorrow to Lady Rutherford and the bereaved family. We are fortunate in having another most famous scientist as our General President and we have every reason to believe that under the guidance of Sir James Jeans, this momentous meeting of the Indian Science Congress will come to a successful issue.

I have chosen for my address the following subjects :

The Conquest of Kala-azar and certain Observations on the Chemotherapy of Malaria.

The earliest epidemic of kala-azar in Bengal occurred in the seventies of the last century, when it was probably complicated with malaria. As I stated elsewhere, in this epidemic it was noted by a contemporary writer that countries that once smiled with peace, health and prosperity had been turned into hot beds of disease, misery and death, and that the fell disease had mocked every human effort, and absorbed in its powerful grasp, day by day and inch by inch, every blessed spot which once used to be prized for its salubrity. This was the old Burdwan fever.

In more recent times the epidemic of the disease in Nowgong district of Assam produced such an appalling mortality that there was a decrease of 31·5 per cent. in population of the place in the decade 1891–1900.

The mortality from the disease has now been reduced from 90% or more to 1 or 2 per cent. Including complicated cases, it has been reduced from 99 to less than 10 per cent.

The conquest of kala-azar may be said to have begun when Cristina and Caronia obtained remarkable results in infantile kala-azar of the Mediterranean basin by the use of tartar emetic. Rogers introduced this drug into India for the treatment of Indian kala-azar and obtained similarly satisfactory results. Soon after the introduction of tartar emetic the speaker introduced sodium antimonyl tartrate for its treatment. This was taken up by others, as the compound was considered to be more powerful and less toxic than tartar emetic.

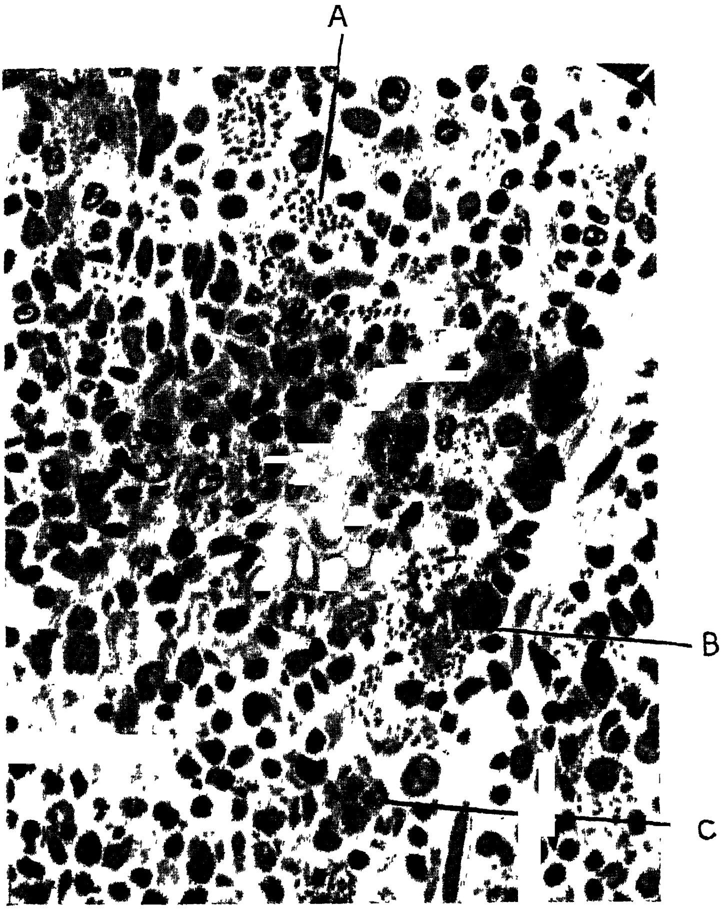
The next step in the treatment of the disease was the introduction by the speaker of intravenous injection of metallic antimony in a state of fine subdivision as an impalpable powder.

It has been observed (Brahmachari and co-workers) that when metallic antimony is injected intravenously in a state of fine subdivision, the particles are picked up by the same cells in the spleen as those that harbour the parasites of kala-azar and that in the struggle that ensues the fight ends most remarkably in the complete destruction of the parasites in the speediest way. (See Plate 5.)

A special outfit has been devised for the intravenous injection of metallic antimony.

The advantage of intravenous injection of metallic antimony is that the number of injections generally required is not more than three or four to bring about complete cure. It is one of the most powerful leishmanocides and may be tried in cases in which other antimonials have failed. The great objection to its use is the complicated technique of the operation of injection which is a serious obstacle in the mass treatment of the disease.

Although treatment with tartar emetic or sodium antimonyl tartrate was very successful in the treatment of kala-azar it was found that in the campaign against the disease it had the disadvantage of being long and tedious. In Assam which was once the hot bed of the disease, treatment was therefore found difficult to enforce, as patients discontinued treatment altogether or attended very irregularly after a few injections. This irregularity made it very difficult to effect complete cures. The Director of Public Health, Assam, once noted that in spite of the regulations in force under the Epidemic Diseases Act to compel patients to undergo a complete course of treatment, the campaign against the disease was greatly handicapped by the large number of patients who stopped treatment. To overcome this difficulty communiques were regularly issued inviting the co-operation of the people. Much propaganda work was done by means of lantern demonstrations and illustrated posters and pamphlets on the disease, emphasising the great dangers of stopping treatment before a complete cure was effected. Though this had some effect in reducing the 'Stopped Treatment' cases, still such cases continued to exist and it was felt that the difficulties in reducing the number of such cases would be overcome more



Photomicrograph of Spleen of a Mouse infected with *Leishmania Donovani* Forty-eight Hours after Intravenous Injection of Metalic Antimony.

A. Cell containing leishmania, but no particles of antimony.
B. Cell with faintly stained cytoplasm containing leishmania and a few particles of antimony.
C. Cell containing coarse granules of antimony and leishmania, some of which appear to be degenerated.

(Reproduced from a paper by the author and co-workers published in the *Transactions of the Royal Society of Tropical Medicine and Hygiene*. Vol. XXIII, No. 6, April, 1930.)

effectively, if some drug could be introduced which would be more efficacious than tartar emetic and take a much shorter time to effect a cure.

The introduction of certain organic compounds of antimony in the treatment of kala-azar infection has been the subject of the speaker's research for many years, and in 1920 some of them were prepared for the first time in India in his laboratory in the Calcutta Campbell Hospital, and he wrote to the Indian Research Fund Association that the potentialities of the preparation of these compounds in India would in future be as great as those of cinchona plantation.

Early in 1921, the speaker discovered an urea antimony compound for the treatment of kala-azar. Its introduction and his other researches on antimonial compounds opened up a new vista in the treatment of the disease by means of therapeutic organic antimonials, just as the discovery of salvarsan led to the introduction of organic arsenicals in the treatment of spirochaetal diseases. This urea compound was named 'urea stibamine'. Soon after its discovery the author suggested to the Director of the Calcutta School of Tropical Medicine the possibility of obtaining therapeutic antimonials from Von Heyden and this led to their introduction into this institution for the treatment of kala-azar.

The first series of cases treated with urea stibamine were published early in 1922. Soon after this, remarkable results were obtained with it by Shortt in Shillong to whom the compound was sent for trial at the instance of the Director of Medical Research appointed by the Government of India. The value of this compound was quickly recognized and it was introduced, after an experimental trial, by the Government of Assam for the mass treatment of kala-azar.

I now proceed to demonstrate the value of urea stibamine in the campaign against kala-azar in Assam as obtained from statistics from the Annual Public Health Reports of the Government of Assam for the years 1925–35 and the Government Resolutions thereon. This drug has been more or less successively in use by the Government of Assam for over twelve years and today it is in universal use in the Province. For some time experiments with neostibosan were conducted side by side with urea stibamine. The use of neostibosan was subsequently discontinued.

In their resolution on the Annual Public Health Reports of the Province of Assam for the year 1926, the Government of Assam noted that the treatment with urea stibamine proved very successful and there was a very satisfactory decrease of over 1,000 in the number of 'Stopped Treatment' cases.

Figure 1 gives the number of cases of kala-azar treated in Assam as a whole from 1925 to 1935 showing a marked fall in the incidence of the disease from 60,940 in 1925 to 11,100 in 1935.

Figure 2 gives the death rate from kala-azar in Assam as a whole from the year 1925 to 1935 showing a marked fall from 6,365 in 1925 to 845 in 1935. Figure 3 gives the number of cases of kala-azar treated in the district of *Sylhet* during the same years showing a marked fall in the incidence of the disease from 10,934 in 1925 to 3,869 in 1935. Figure 4 gives the death rate from the disease in the district of Sylhet from the year 1925 to 1935 showing a marked fall from 2,109 in 1925 to 260 in 1935. Figure 5 gives the number of cases of kala-azar treated in the district of *Goalpara* during the same years showing a marked fall in the incidence of the disease from 6,003 in 1925 to 1,245 in 1935. Figure 6 gives the death rate from the disease from the same years in *Goalpara* showing a marked fall from 453 in 1925 to 100 in 1935. Figure 7 gives the number of cases of the disease treated in the district of *Kamrup* during the same years showing a marked fall in the incidence of the disease from 8,753 in 1925 to 1,465 in 1935. Figure 8 gives the death rate for the same years in the district of *Kamrup* from the years 1925 to 1935 showing a marked fall from 1,120 in 1925 to 176 in 1935. Figure 9 gives the number of cases treated in the district of *Darrang* during the same years showing a marked fall in the incidence of the disease from 5,262 in 1925 to 738 in 1935. Figure 10 gives the death rate for the same years in the district of *Darrang* for the years 1925 to 1935 showing a marked fall from 478 in 1925 to 91 in 1935. Figure 11 gives the number of cases treated in the district of *Nowgong* during the same years showing a marked fall in the incidence of the disease from 13,895 in 1925 to 1,651 in 1935. Figure 12 gives the death rate from the disease for the same years in the district of *Nowgong* showing a marked fall from 1,445 in 1925 to 52 in 1935. Figure 13 gives the number of cases treated in the *Garo Hills* during the same years showing a marked fall in the incidence of the disease from 1,952 in 1925 to 690 in 1935. Figure 14 gives the death rate from the disease for the same years in the *Garo Hills* showing a marked fall from 435 in 1925 to 58 in 1935.

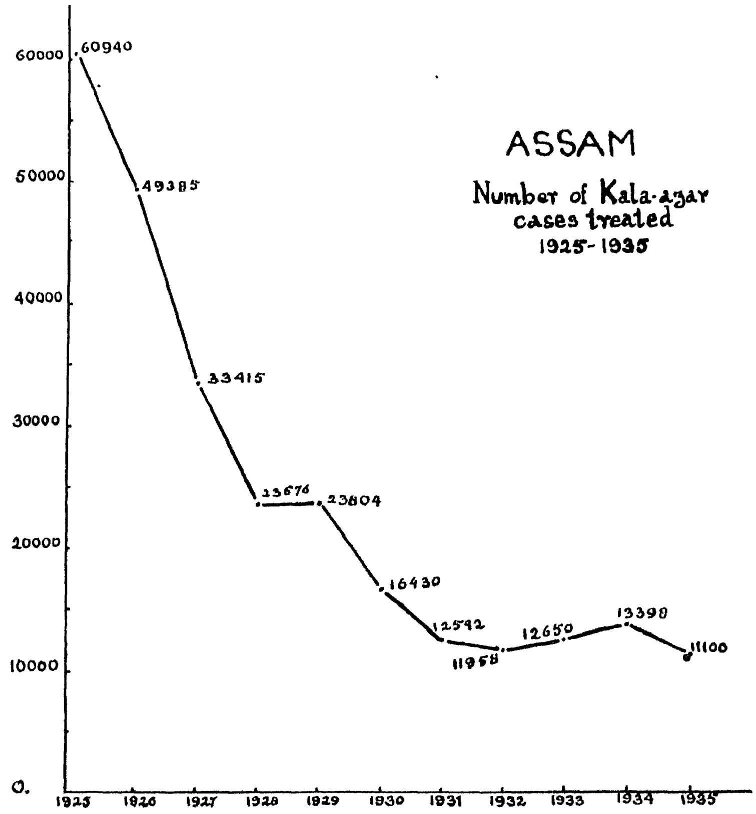

ASSAM
Number of Kala-azar cases treated 1925-1935
60000
50000
40000
30000
20000
10000
0.
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
60940
49385
33415
23676
23804
16430
12592
11958
12650
13398
11100

FIG. 1.

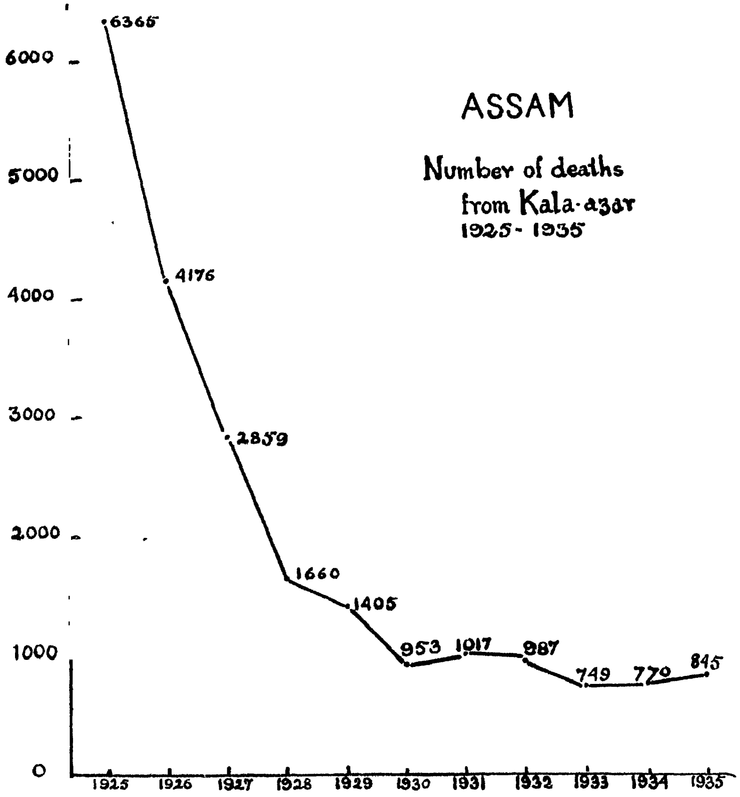

ASSAM
Number of deaths from Kala-azar 1925-1935
6000
5000
4000
3000
2000
1000
0
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
6365
4176
2859
1660
1405
953
1017
987
749
770
845

FIG. 2.

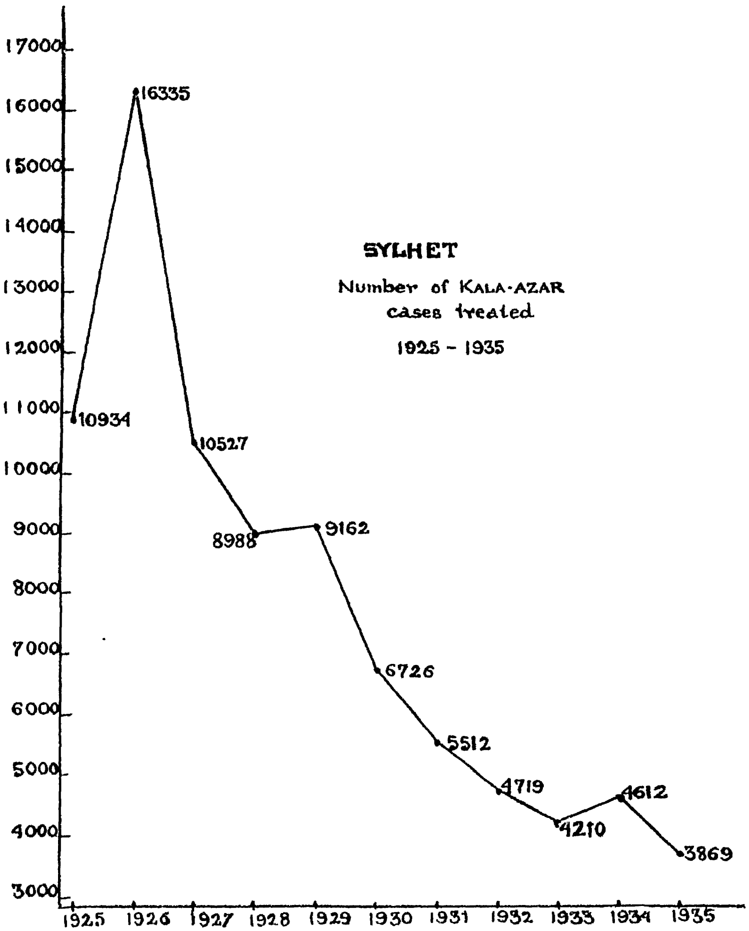

SYLHET
Number of KALA-AZAR cases treated
1925 - 1935
17000
16000
15000
14000
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
3000
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
10934
16335
10527
8988
9162
6726
5512
4719
4210
4612
3869

FIG. 3.

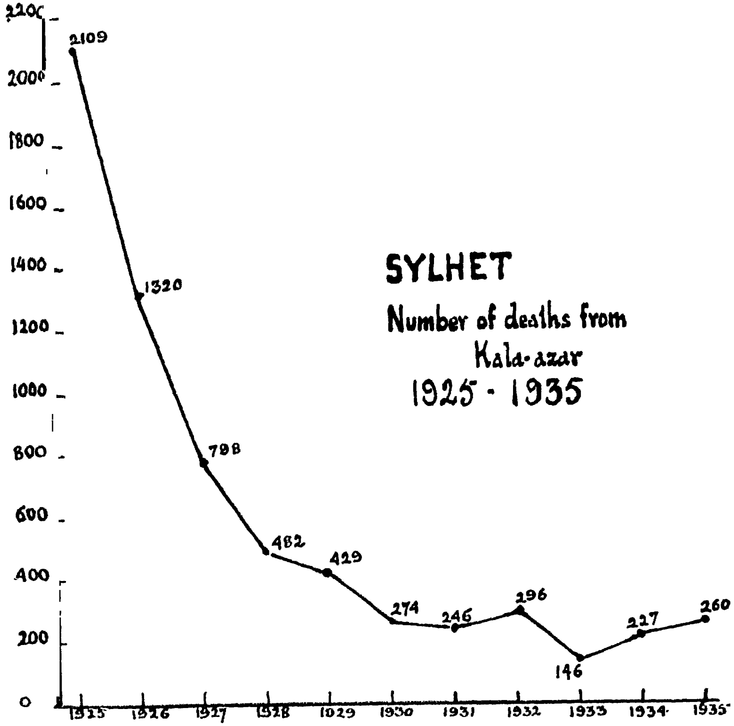

SYLHET
Number of deaths from Kala-azar
1925 - 1935
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
2109
1320
798
482
429
274
246
296
146
227
260

FIG. 4.

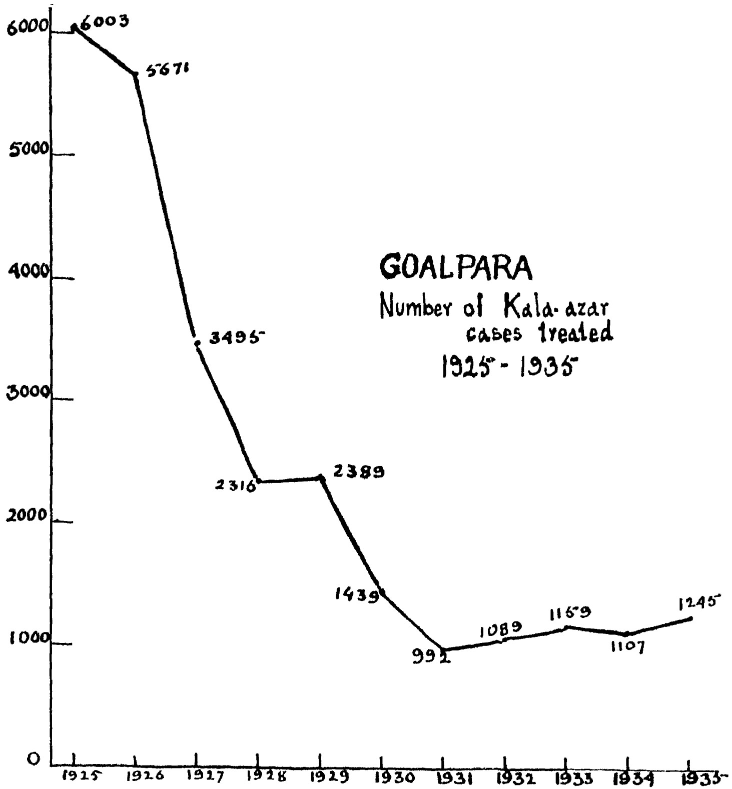

GOALPARA
Number of Kala-azar cases treated
1925 - 1935
6000
5000
4000
3000
2000
1000
0
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
6003
5671
3495
2316
2389
1439
992
1089
1159
1107
1245

FIG. 5.

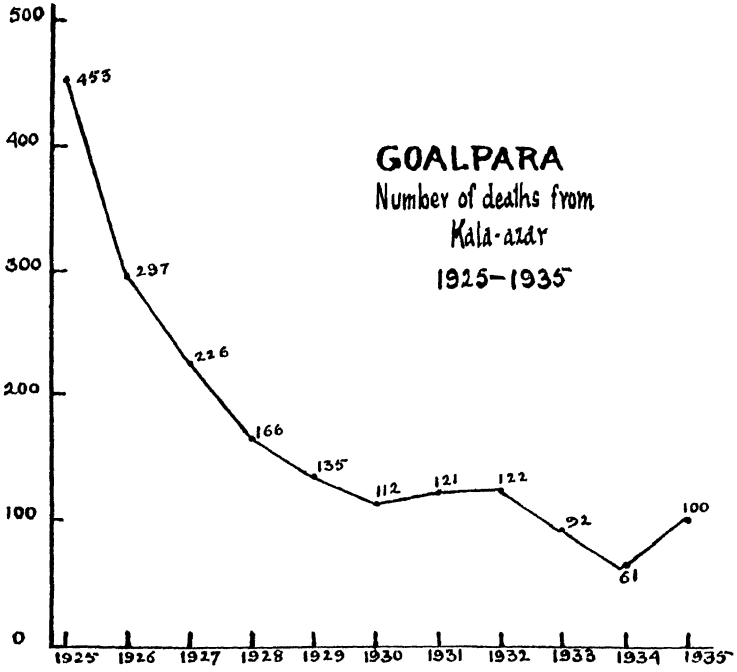
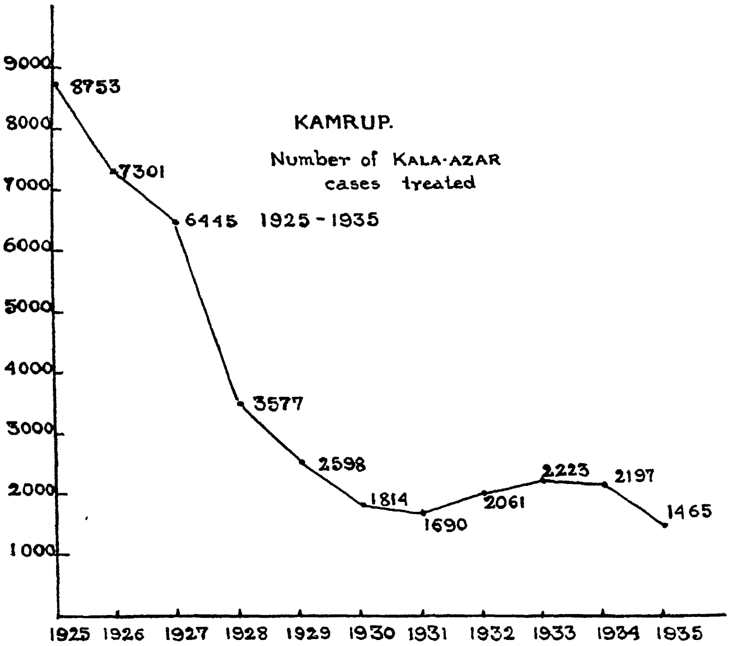
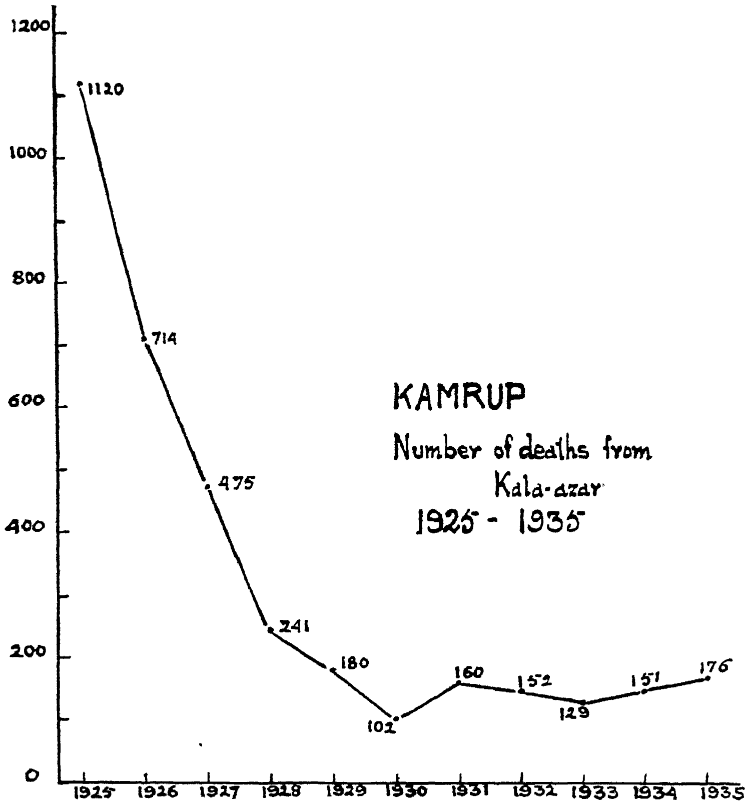

GOALPARA
Number of deaths from Kala-azar
1925–1935
500
400
300
200
100
0
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
455
297
226
166
135
112
121
122
92
61
100

FIG. 6.



KAMRUP.
Number of KALA-AZAR cases treated
1925 - 1935
9000
8000
7000
6000
5000
4000
3000
2000
1000
8753
7301
6445
3577
2598
1814
1690
2061
2223
2197
1465
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935

FIG. 7.



KAMRUP
Number of deaths from Kala-azar
1925 - 1935
1200
1000
800
600
400
200
0
1120
714
475
241
180
102
160
152
129
151
176
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935

FIG. 8.

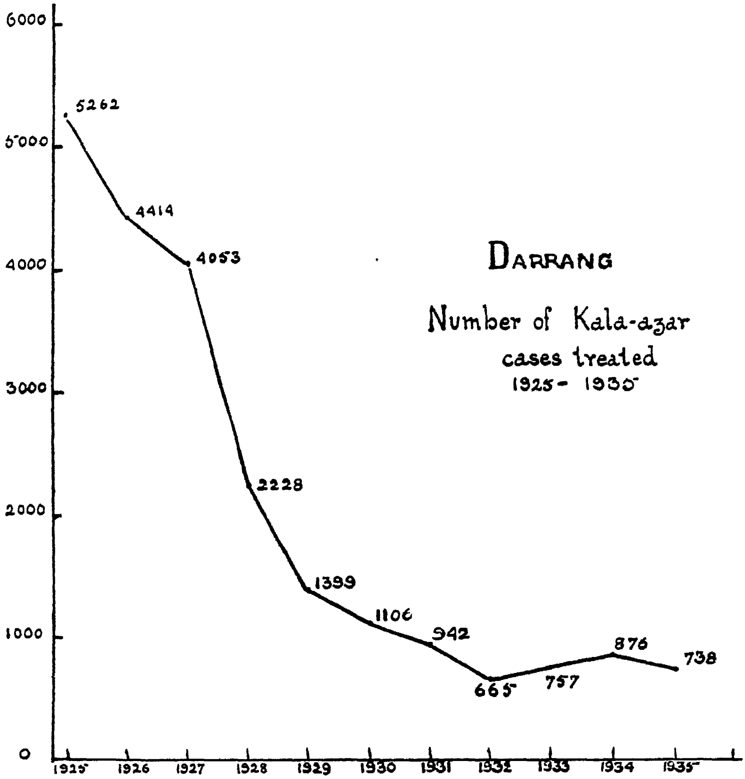

6000
5000
4000
3000
2000
1000
0
5262
4414
4053
2228
1399
1106
942
665
757
876
738
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
Darrang
Number of Kala-azar cases treated
1925- 1935

FIG. 9.

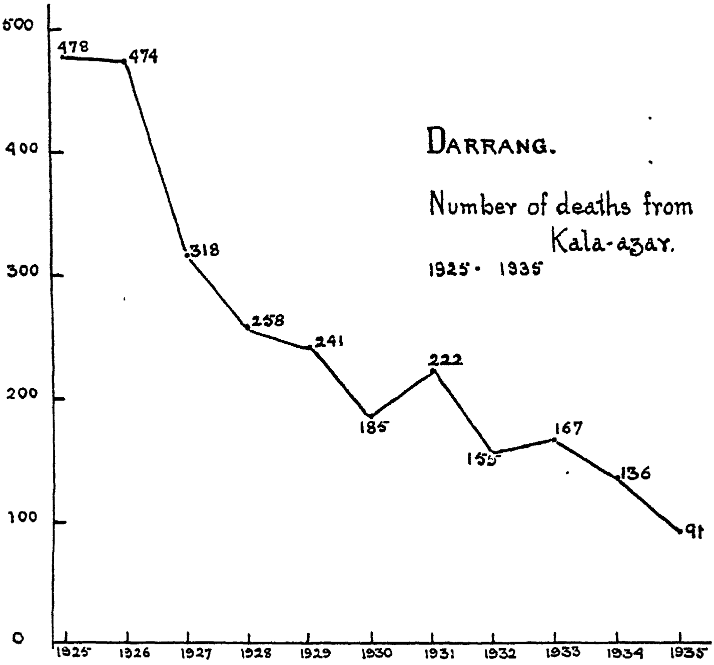

500
400
300
200
100
0
478
474
318
258
241
185
222
155
167
136
91
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
Darrang.
Number of deaths from Kala-azar.
1925 - 1935

FIG. 10.

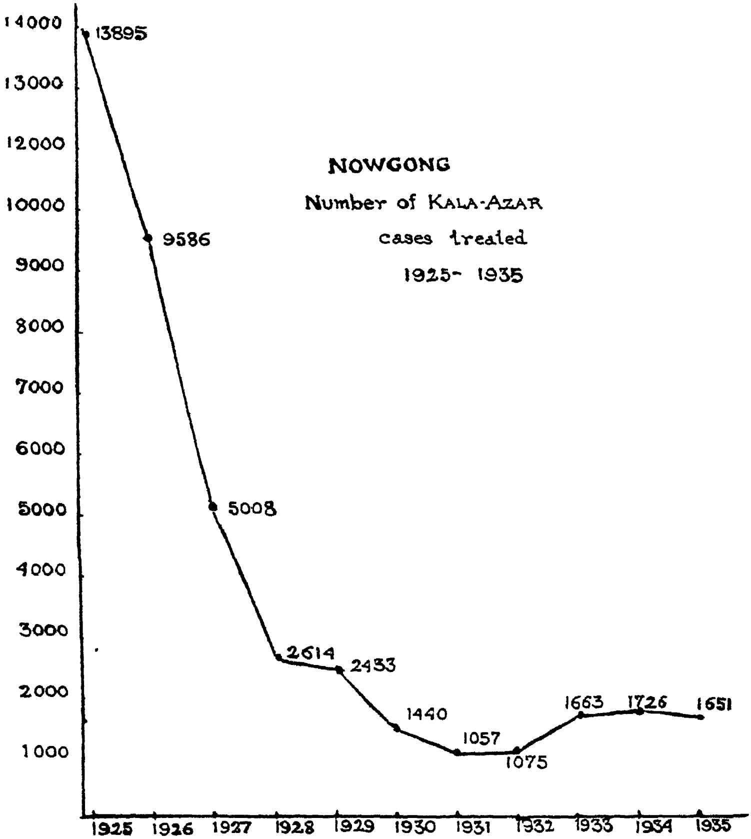

NOWGONG
Number of KALA-AZAR
cases treated
1925- 1935
14000
13000
12000
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
13895
9586
5008
2614
2433
1440
1057
1075
1663
1726
1651
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935

FIG. 11.

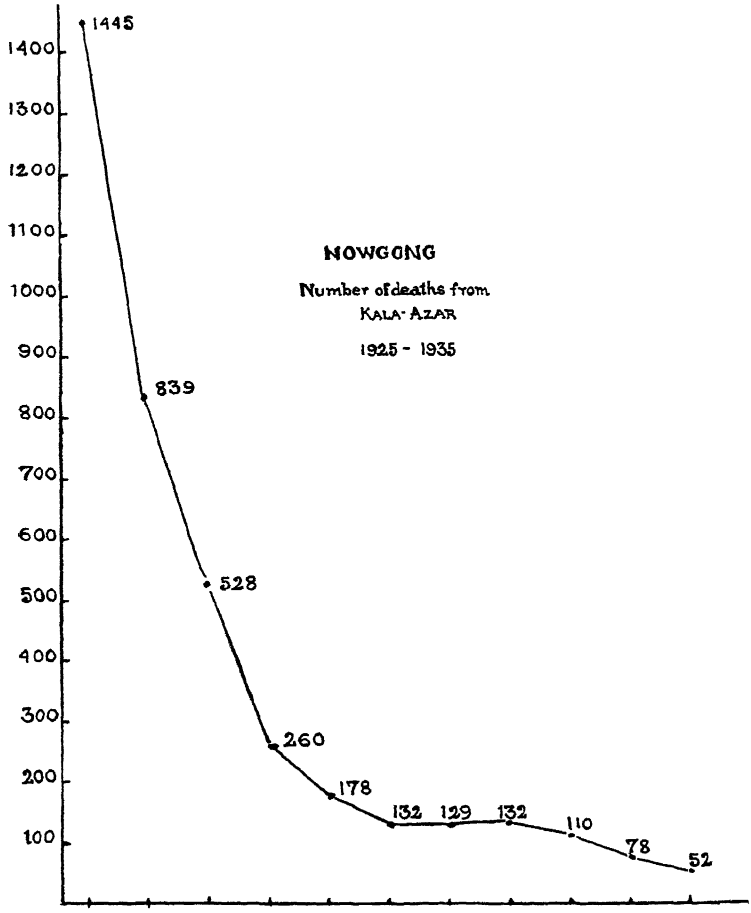

NOWGONG
Number of deaths from
KALA-AZAR
1925 - 1935
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
1445
839
528
260
178
132
129
132
110
78
52
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935

FIG. 12.

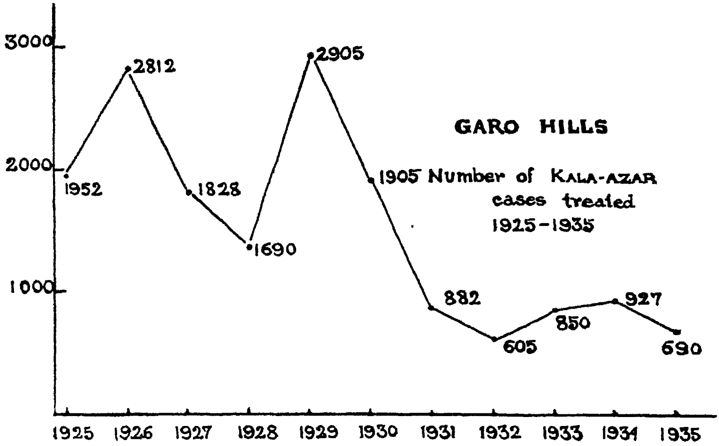

GARO HILLS
Number of KALA-AZAR cases treated 1925–1935
3000
2000
1000
1952
2812
1828
1690
2905
1905
882
605
850
927
690
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935

FIG. 13.

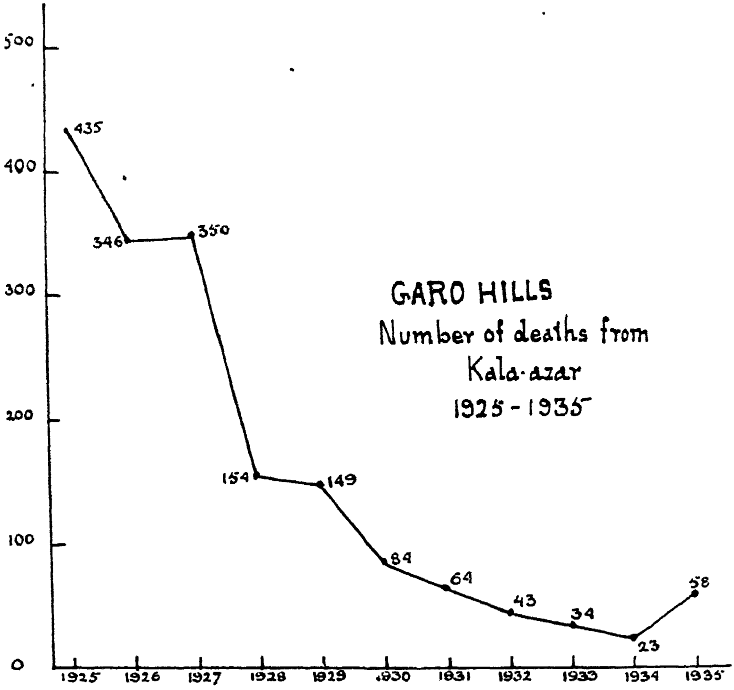

GARO HILLS
Number of deaths from Kala-azar
1925 - 1935
500
400
300
200
100
0
435
346
350
154
149
84
64
43
34
23
58
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935

FIG. 14.

STATISTICS OF NUMBER OF KALA-AZAR CASES TREATED BY THE GOVERNMENT OF ASSAM AND THE NUMBER OF DEATHS FROM THE DISEASE

PROVINCE OF ASSAM AS A WHOLE

Year	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
No. of cases treated	60,940	49,385	33,415	23,576	23,804	16,430	12,592	11,958	12,650	13,398	11,100
No. of deaths	6,365	4,176	2,859	1,660	1,405	953	1,017	987	749	770	845

DISTRICTS

Sylhet

Year	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
No. of cases treated	10.934	16.335	10,527	8,988	9,162	6,726	5,512	4,719	4,210	4,612	3,869
No. of deaths	2,109	1,320	798	482	429	274	246	296	146	227	260

Goalpara

Year	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
No. of cases treated	6,003	5,671	3,495	2,316	2,389	1,439	992	1,089	1,159	1,107	1,245
No. of deaths	453	297	226	166	135	112	121	122	92	61	100

Kamrup

Year	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
No. of cases treated	8,753	7,301	6,445	3,577	2,598	1,814	1,690	2,061	2,223	2,197	1,465
No. of deaths ..	1 120	714	475	241	180	102	160	152	129	151	176

Darrang

Year	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
No. of cases troated	5.262	4,414	4,053	2,228	1,399	1,106	942	665	757	876	738
No. of deaths ..	478	474	318	258	241	185	222	155	167	136	91

Nowgong

Year	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
No. of cases treated	13,895	9,586	5,008	2,614	2,433	1,440	1,057	1,075	1,663	1,726	1,651
No. of deaths ..	1,445	839	528	260	178	132	129	132	110	78	52

Garo Hills

Year	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935
No. of cases treated	1,952	2,812	1,828	1,690	2,905	1,905	882	605	850	927	690
No of deaths ..	435	346	350	154	149	84	64	43	34	23	58

The number of cases treated and of deaths in 1936 could not be incorporated in the above Figures and Tables, as the Annual Health Report for 1936 was not available when the figures and tables were printed off. Fig. 15 gives a comparative

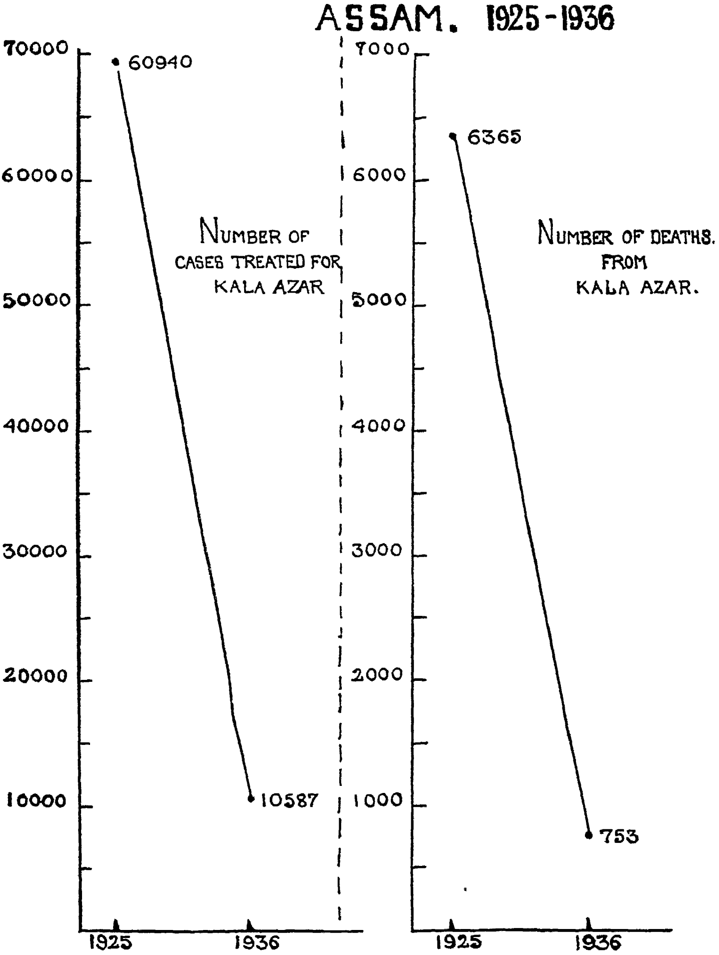


FIG. 15.

statement of the number of cases treated and deaths in the Province of Assam from 1925 to 1936.

The figures for Cachar which are not exhibited in the above diagrams are very interesting. Out of 5,188 cases treated from 1925 to 1936, the number of deaths was 56 showing a percentage of less than 1·08 per cent. Out of 574 cases treated in 1936 the number of deaths was 2 showing a percentage of less than 0·3 per cent.

It will be seen from the above Figures and Tables that the effect of the treatment with urea stibamine during the above mentioned years on the incidence of kala-azar in Assam and its mortality has been phenomenal. The disease has lost all its terrors in the Province and people who suffer from it are less afraid than those who suffer from malaria.

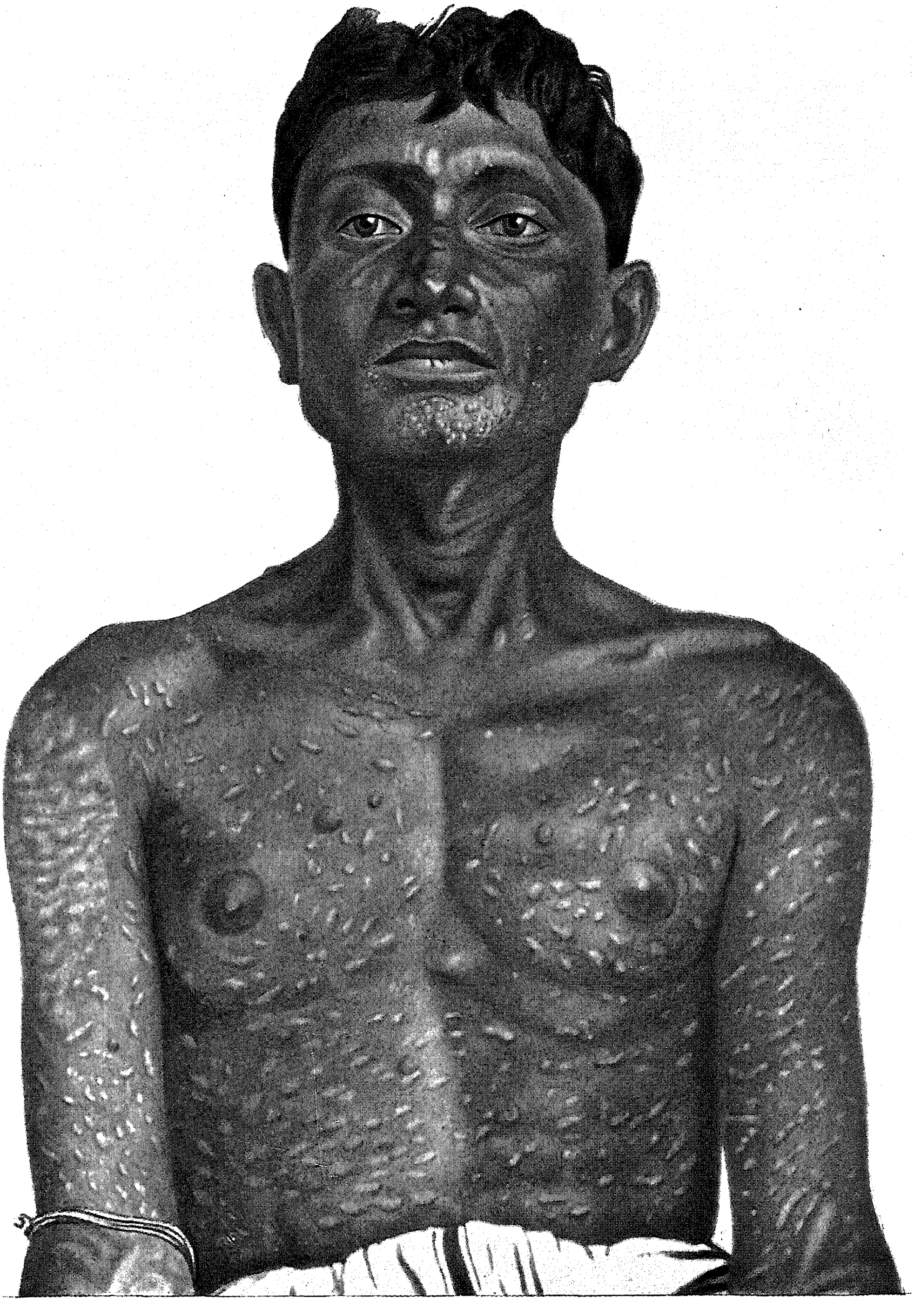
The Kala-azar Commission, India, used, throughout the seven years of their existence, urea stibamine only, in the routine treatment of kala-azar. According to them the acute fulminating type characteristic of the peak period of an epidemic responded to treatment with urea stibamine extraordinarily promptly and with an almost dramatic cessation of fever, diminution in size of the spleen and return to normal condition of health. It may be expected that similar beneficial results will be obtained in other epidemics of the disease.

In 1933, the Director of Public Health, Assam, noted that 'urea stibamine was our mainstay in the treatment of kala-azar'. 'Since 1923, when reliable figures for the diseases first became available to end of the year under report, no less than 328,591 persons have been brought under treatment. It is no exaggeration to say that approximately 3·25 lacs of valuable lives have been saved to the Province.'

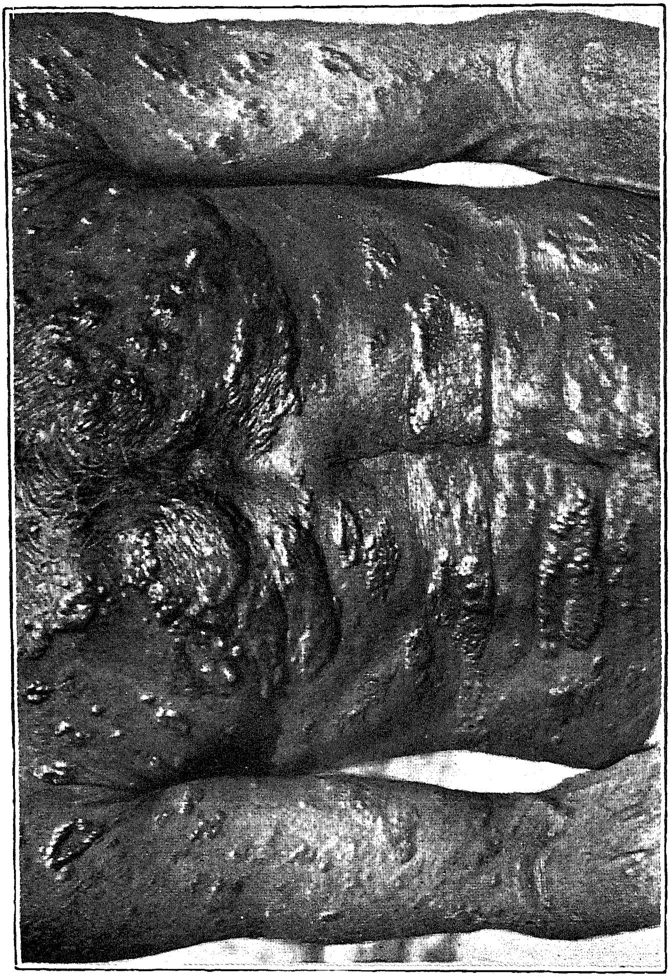
Sir John Kerr, once Governor of Assam in his farewell address to the Assam Legislative Council referring to the value of urea stibamine stated that 'the progress in the campaign against kala-azar in Assam has been phenomenally rapid and if it continues at the present rate there is an excellent prospect of the dread scourge being brought under complete control in a few years'. This has now come to pass, as you have just seen from the statistics quoted in the present address, and as was once predicted by the Director of Public Health, Assam, one day we shall be successful in stamping the disease out of the Province. The same may also be said of other parts of the world where the disease occurs. The discovery of a powerful specific for the disease, its limited distribution and rarity of relapses lend support to this conclusion.

A few antimonials have been tried intramuscularly in the treatment of kala-azar. Among these may be mentioned sodium-N-phenyl-glycine-amide-4-stibinate (antimony analogue of tryparsamide) and sodium-sulphomethylene-stibanilate (antimony analogue of sulph-arsenol) which have been successfully used by the author, while neostibosan has been used with success by Napier.

In studying the treatment of kala-azar one finds that the enemy in the process of destruction tries to retreat from the internal organs to some other parts of body, just as it is noticed



First case of Dermal Leishmanoid.
(Reproduced from a paper by the author published in the *Indian Medical Gazette*, Vol. LVII, No. 4, April, 1922.)



Showing extensive annular lesions in trunk in front and the arm.

(Reproduced from a paper by P. N Brahmachari published in the *Transactions of the Royal Society of Tropical Medicine and Hygiene*, Vol. XXVIII, No. 2, August, 1934.)

in the case of human warfare the conquered foe tries to hide himself in hills and jungles to elude the pursuit of the conquerors. This was first discovered in 1922 when the speaker observed certain remarkable skin eruptions caused by ***Leishmania donovani*** developing in kala-azar patients two or three years after completion of antimonial treatment and apparent cure, though under ordinary conditions, in kala-azar the skin shows very little involvement or none. Originally considered very rare, these skin lesions have been subsequently found not to be an uncommon condition.

The disease was named dermal leishmanoid by the speaker when first discovered, and subsequently called dermal leishmaniasis in the Carmichael Hospital for Tropical Diseases attached to the Calcutta School of Tropical Medicine.

The various types of the disease will not be described here in detail.

The photographs of the first recorded case of dermal leishmanoid as well as of a case of annular variety of the disease are reproduced here (Plates 6 and 7).

The photomicrographs of sections of skin showing the presence of leishmania-laden cells just under the epidermal layer and of leishmania-laden pigment-carrying cells in the superficial layer of the dermis are shown in Plate 8.

Viable leishmania have been cultured from these skin lesions in test tubes and sandflies. They are therefore a source of infection and the conquest of kala-azar cannot be regarded complete unless these lesions are either averted or quickly cured. Not infrequently, they take a prolonged course of antimonial treatment and some of them are very resistant and may be dangerous carriers of antimony-resistant parasites. The author has recommended combined treatment with intravenous injection of urea stibamine and inunction of metallic antimony.

It is evident that in the campaign against kala-azar and its conquest, proper handling of cases of dermal leishmanoid is an important point to be taken into consideration.

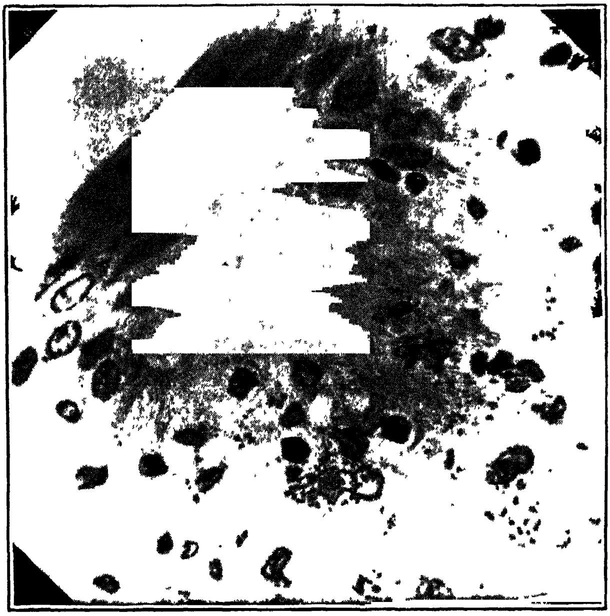
The constitution of urea stibamine has been a matter of some controversy. As pointed out by Gray and co-workers it is the most interesting of therapeutic antimonials. Originally considered by the speaker to be urea salt of para-amino-phenyl stibinic acid, it was subsequently considered by him to be ammonium carbamino-stibanilate. More recently Gray and co-workers have studied the chemical constitution and physiological properties of the compound carefully and exhaustively in an important paper in the *Proceedings of the Royal Society* (1931). They have shown that urea stibamine is disubstituted urea consisting mostly of S-diphenylcarbamide-4 : 4'-distibinic acid as its active organo-metallic constitution, containing some amount of protective colloids to make it water-soluble. Its constitution is therefore, according to these observers, different from that of compounds of the type of neostibosan or neostam which are salts of para-aminophenyl-stibinic acid.

The conquest of kala-azar by campaign against the disease by treatment of the affected individuals is, from what I have shown, one of the most remarkable feats in chemotherapy. Whether a prophylactic dose of urea stibamine to persons living in kala-azar infected areas just like the prophylactic use of quinine in malaria will be of any value or whether an inunction of metallic antimony may be recommended to be used by them as a routine practice is a matter of investigation.

I now pass on from the conquest of kala-azar, to certain observations on the chemotherapy of antimalarial quinoline and acridine compounds, which may one day play an important part in the campaign against malaria and its conquest.

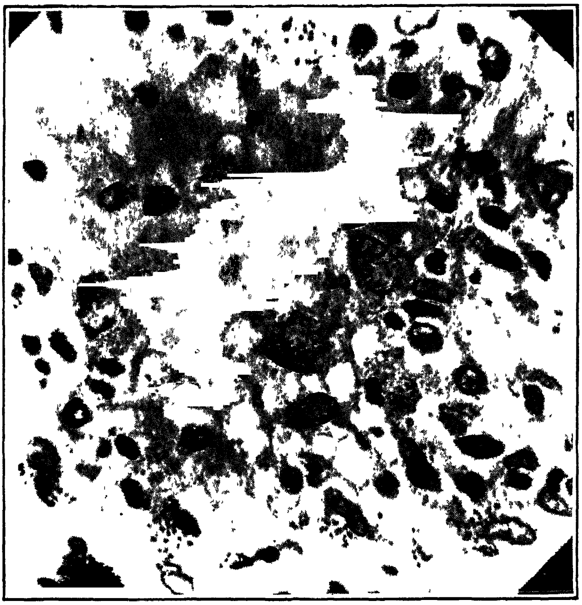
In most of the Eastern parts of India malaria and kala-azar go together. They have many symptoms in common and were confused with each other for a long time.

Research in chemotherapy of malaria has been intense in recent times. In certain parts of India it is of greater interest than kala-azar. For sometime past, work in this line has been undertaken by the speaker and co-workers and new quinoline compounds synthesized with the view of studying their action on paramoecia as well as on the parasites of malaria. While, as will be seen from the accompanying tables, some of these compounds have marked destructive action on paramoecia, most of them have been observed to have no action on the parasites of malaria when used clinically in patients suffering from the disease.



Photomicrograph of a section of the skin showing leishmania-laden cells just under the epidermal layer.

(P. N. Brahmachari.)

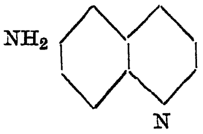
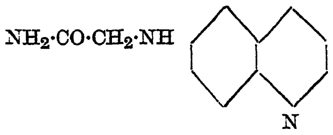
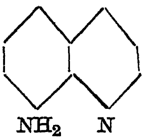
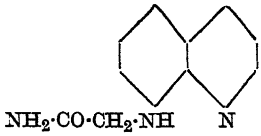
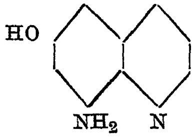
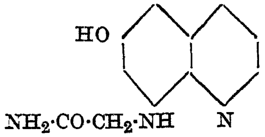
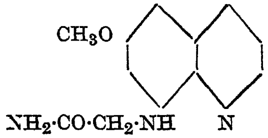


Photomicrograph of a section of the skin showing leishmania laden pigment-carrying cells in the superficial layer of dermis.

(P. N. Brahmachari.)

TABLE I

Action of certain quinoline compounds on paramoecia

	STRENGTH	EFFECT ON PARAMOECIA
I. 6-amino-quinoline 	1 : 2,000 1 : 4,000	Death No death
II. Quinoline-6-glycine-amide 	1 : 2,000 1 : 4,000	Death No death
III. 8-amino-quinoline 	1 : 2,000 1 : 4,000	No death No death
IV. Quinoline-8-glycine-amide 	1 : 2,000	No death
V. 6-oxy-8-amino-quinoline 	1 : 2,000 1 : 10,000 1 : 20,000 1 : 40,000 1 : 80,000 1 : 160,000 1 : 320,000	Death in 6 minutes Death in 7 minutes Death in 7 minutes Death in 8 minutes Death in 14 minutes Death in 17 minutes No death in 1 hour
VI. 6-oxy-quinoline-8-glycine-amide 	1 : 200 1 : 10,000 1 : 20,000 1 : 40,000 1 : 80,000 1 : 160,000 1 : 320,000	Death in 7 minutes Death in 7 minutes Death in 10 minutes Death in 11 minutes Death in 15 minutes Death in 19 minutes No death
VII. 6-methoxy-quinoline-8-glycine-amide 	1 : 1,000	No action

For purpose of comparison we append here the action of quinine hydrochloride on paramoecia under conditions similar to the above.

	STRENGTH	EFFECT ON PARAMOECIA
Quinine hydrochlor	1 : 10,000	Death in 5 minutes
	1 : 20,000	Death in 10 minutes
	1 : 40,000	Death in 19 minutes
	1 : 80,000	Death in 35 minutes
	1 : 160,000	No death in 1 hour

(Reproduced from a paper by the author and co-workers published in the *Journal of Pharmacology and Experimental Therapeutics,* Vol XXXIX, No. 4, August, 1930.)

TABLE II

Action of certain quinoline compounds on paramoecia

	STRENGTH	EFFECT ON PARAMOECIA
I. 6-amino-4-phenyl-quinaldine hydrochloride	1 : 2,000	No death in 1 hour
	1 : 10,000	No death in 1 hour
II. 8-amino-4-phenyl-quinaldine hydrochloride	1 : 2,000	Death in 4 minutes
	1 : 10,000	Death in 24 minutes
	1 : 20,000	A few dead in 1 hour
	1 : 40,000	No death in 1 hour

(Reproduced from a paper by the author and co-workers published in the *Journal of Pharmacology and Experimental Therapeutics,* Vol. XLI, No. 3, March, 1931.)

TABLE III

Action of certain quinoline compounds on paramoecia

	STRENGTH	EFFECT ON PARAMOECIA
1. 8-amino-quinoline-para-arsanilate	1 : 2,000	A few death in 1 hour
	1 : 10,000	No death in 1 hour
2. 6-amino-quinoline-para-arsanilate	1 : 2,000	No death in 1 hour
	1 : 10,000	No death in 1 hour
3. 8-amino-ethyl-amino-quinoline hydrochloride (Robinson)	1 : 2,000	Death in 3 minutes
	1 : 10,000	Death in 29 minutes
	1 : 20,000	No death in 1 hour
4. 8-amino-isopropyl-amino-quinoline hydrochloride	1 : 2,000	Death in 20 minutes
	1 : 10,000	Death in 35 minutes
	1 : 20,000	90 per cent. death in 1 hour
	1 : 40,000	No death in 1 hour
5. 6-methoxy-8-amino-iso-propyl-amino-quinoline di-hydrochloride	1 : 2,000	A few dead in 1 hour
	1 : 10,000	No death in 1 hour
6. 6-chloro-8-amino-isopropyl-amino-quinoline di-hydrochloride	1 : 2,000	Death in 1 minute
	1 : 10,000	Death in 4 minutes
	1 : 20,000	Death in 12 minutes
	1 : 40,000	Death in 30 minutes
	1 : 80,000	No death in 1 hour
	1 : 100,000	No death in 1 hour
7. 6-chloro-2-methyl-8-amino-isopropyl-amino-quinoline di-hydrochloride	1 : 2,000	Death in 30 minutes
	1 : 10,000	No death in 1 hour
8. Amino-acetyl derivative of 8-amino-ethyl-amino quinoline	1 : 2,000	90 per cent. death in 1 hour
	1 : 10,000	No death in 1 hour

(Reproduced from a paper by P. Brahmachari, U. Brahmachari and R. Banerjea published in the *Journal of Pharmacology and Experimental Therapeutics*, Vol. XLIV, No. 4, April, 1932.)

TABLE IV

Action of certain quinoline compounds on paramoecia

	Strength	Effect on paramoecia
1. Allyl-8-amino-quinoline hydrochloride	1 : 2,000 1 : 10,000	Death in 5 minutes No death in 1 hour
2. Allyl-thio-carbamino-8-amino-quinoline hydrochloride	1 : 2,000 1 : 10,000	No death in 1 hour No death in 1 hour
3. 6-methoxy-8-β-dimethyl-amino-isopropyl-amino-quinoline dihydrochloride	1 : 2,000 1 : 10,000	Death in 14 minutes No death in 1 hour
4. 6-methyl-8-β-dimethyl-amino-isopropyl-amino-quinoline dihydrochloride	1 : 2,000 1 : 10,000	Death in 1 hour No death in 1 hour
5. 2-methyl-6-methoxy-8-β-dimethyl-amino-iso-propyl-amino-quinoline dihydrochloride	1 : 2,000 1 : 10,000 1 : 20,000	Death in 28 minutes Death in 1 hour No death in 1 hour
6. Lactyl-8-amino-quinoline hydrochloride	1 : 2,000 1 : 10,000 1 : 20,000 1 : 40,000 1 : 80,000	Death in 12 minutes Death in 28 minutes Death in 35 minutes Death in 1 hour No death in 1 hour
7. β-hydroxy-propyl-8-amino-quinoline hydrochloride	1 : 2,000 1 : 10,000	Death in 45 minutes No death in 1 hour
8. 6-ethoxy-β-hydroxy-propyl-8-amino-quinoline-hydrochloride	1 : 2,000 1 : 10,000	No death in 1 hour No death in 1 hour
9. 6-ethoxy-lactyl-8-amino-quinoline-hydrochloride	1 : 2,000 1 : 10,000	Death in 18 minutes No death in 1 hour
10. 6-methoxy-8-β-diethyl-amino-isopropyl-amino-quinoline dihydrochloride	1 : 2,000 1 : 10,000	No action in 1 hour No action in 1 hour
11. 8-(β-piperidino-isopropyl-amino)-quinoline dihydrochloride	1 : 2,000 1 : 10,000 1 : 20,000 1 : 40,000 1 : 80,000 1 : 100,000	Immediate death Death in 2 minutes Death in 10 minutes Death in 11 minutes Death in 15 minutes Death in 35 minutes

(Reproduced from a paper by P. Brahmachari, R. Banerjea, and U. Brahmachari published in the *Journal of Pharmacology and Experimental Therapeutics*, Vol. XLVIII, No. 2, June, 1933.)

Apart from the variability in the value of the hitherto-known quinoline and acridine derivatives in their destructive action on the different types of malarial parasites or on the schizonts and gametocytes of the same parasite or its strains, these compounds sometimes exhibit toxic symptoms of varying intensity and this is sufficient justification for further research on synthetic antimalarials.

Of late, a compound having the same composition as quinacrine or atebrin has been synthesized in the speaker's laboratory.

As expected, it has well-marked antimalarial properties as will be presently seen. It is provisionally named Acridin X or Ax. The compound has been used by the speaker as hydrochloride or hydrobromide. The following is the first series of cases treated in the Tropical Diseases Ward of the Carmichael Medical College Hospitals, Calcutta. Its action on paramoecia is shown in the accompanying table. Its action in monkey malaria has been studied by Shortt and Menon.

ACTION OF ACRIDIN X ON PARAMOECIA

Experiment No. I

	STRENGTH	EFFECT ON PARAMOECIA
Acridin X	1 : 1,000	Death in 2 to 4 minutes
	1 : 5,000	Death in 4 to 6 minutes
	1 : 10,000	Death in 8 to 10 minutes
	1 : 40,000	Death in 12 to 15 minutes
	1 : 80,000	Majority died in ¾ of an hour
	1 : 100,000	Majority died in 1¼ of an hour
	1 : 120,000	Few deaths in 1½ of an hour
	1 : 160,000	No death in 2 hours.

Experiment No. II

	STRENGTH	EFFECT ON PARAMOECIA
Acridin X	1 : 1,000	Death in 3 minutes
	1 : 5,000	Death in 3 to 5 minutes
	1 : 10,000	Death in 7 to 10 minutes
	1 : 40,000	Death in 10 to 14 minutes
	1 : 80,000	Majority died in 1½ hours
	1 : 100,000	Majority died in 1½ of an hour
	1 : 120,000	Few deaths in 2 hours.
	1 : 160,000	No death in 2½ hours

Experiment No. III

	STRENGTH	EFFECT ON PARAMOECIA
Acridin X	1 : 1,000	Death in 2 to 5 minutes
	1 : 5,000	Death in 4 to 6 minutes
	1 : 10,000	Death in 6 to 9 minutes
	1 : 40,000	Death in 10 to 15 minutes
	1 : 80,000	Majority died in 62 minutes
	1 : 100,000	Majority died in 1½ hours (few survived)
	1 : 120,000	Few deaths in 2 hours
	1 : 160,000	No death in 2½ hours

A Series of Cases of Malarial Fever treated with Acridin X.

No I.—Patient K, aet 25, was admitted on 4-2-37. History of fever for two months. Patient was put on Ax from 5-2-37 in 1½ grs. doses thrice a day. The effect of the treatment is shown in Chart I. On 4-2-37, B.T. trophozoites were present in blood; on 7-2-37, no malarial parasites were found; on 4-2-37, spleen was 3″ below costal margin; on 11-2-37, spleen was just felt below costal margin.

No. II.—Patient B, aet 20, was admitted on 13-1-37. History of fever for 15 days. Patient was put on Ax from 14-1-37 in 1½ grs. doses thrice a day. The effect of the treatment is shown in Chart II. On 13-1-37, B.T. trophozoites and gametocytes were present in blood; on 17-1-37, no malarial parasites were found; on 13-1-37, spleen was 1½″ below costal margin; on 8-2-37, spleen was not palpable below costal margin.

No. III.—Patient D, aet 18, was admitted on 9-11-36. History of fever for two months. Patient was put on Ax from 12-11-36 in 2¼ grs. doses thrice a day. The effect of the treatment is shown in Chart III. On 10-11-36, B.T. and M.T. trophozoites were present in blood; on 13-11-36, no malarial parasites were found; on 9-11-36, spleen was hard and 2″ below costal margin; on 17-2-37, spleen was just felt below costal margin.

No. IV.—Patient C, aet 16, was admitted on 2-3-37. History of fever for 2½ months. Patient was put on Ax from 3-3-37 in 1½ grs. doses thrice a day. The effect of treatment is shown in Chart IV. On 3-3-37, M.T. rings and crescents were present in the blood; on 7-3-37, only crescents were found; on 2-3-37, spleen was 1″ below costal margin; on 8-4-37, spleen was just felt below costal margin.

No. V.—Patient B, aet 12, was admitted on 23-3-37. History of fever for 3 days. Patient was put on Ax from 25-3-37 in ·75 grs. doses thrice a day. The effect of the treatment is shown in Chart V. On 23-3-37, B.T. trophozoites were present in the blood; on 28-3-37, no malarial parasites were found; on 23-3-37, spleen was moderately hard and 2″ below costal margin; on 1-4-37, spleen was felt just below costal margin.

No. VI.—Patient R, aet 32, was admitted on 24-3-37. History of fever for 8 days. Patient was put on Ax from 25-3-37 in 1½ grs. doses thrice a day. The effect of the treatment is shown in Chart VI. On 24-3-37, M.T. rings were present in the blood; on 30-3-37, only crescents were found; on 24-3-37, spleen was 1⅓″ below costal margin; on 9-4-37, spleen was just felt below costal margin.

No. VII.—Patient B, aet 30, was admitted on 13-9-37. History of fever for 28 days. Patient was put on Ax from 16-9-37 in 2¼ grs. doses twice a day. The effect of treatment is shown in Chart VII. On 13-9-37, M.T. trophozoites were present in blood; on 19-9-37, no malarial parasites were found; on 13-9-37, spleen was 1″ below costal margin; on 27-9-37, spleen was not palpable below costal margin.

No. VIII.—Patient R, aet 30, was admitted on 20-9-37. History of fever for 4 days. Patient was put on Ax from 23-9-37 in 1½ grs. doses twice a day. The effect of the treatment is shown in Chart VIII. On 37-20-9, plenty of M.T. rings were present in the blood; on 25-9-37, only crescents were found; on 20-9-37, spleen was 1″ below costal margin; on 25-9-37, spleen was not palpable below costal margin.

No. IX.—Patient M, aet 15, was admitted on 7-10-37. History of fever for 5 days. Patient was put on Ax from 10-10-37 in 1½ grs. doses twice a day. The effect of the treatment is shown in Chart IX. On 8-10-37, B.T. trophozoites were present in blood; on 12-10-37, no malarial parasites were found; on 7-10-37, spleen was 1¼″ below costal margin; on 15-10-37, spleen was ½″ below costal margin.

No. X.—Patient G, aet 20, was admitted on 6-10-37. History of fever for 6 days. Patient was put on Ax from 8-10-37 in 1½ grs. doses twice a day. The effect of the treatment is shown in Chart X. On 6-10-37, M.T. rings were present in blood; on 10-10-37, only crescents were found; on 6-10-37, spleen was 1½″ below costal margin; on 15-10-37, spleen was ¼″ below costal margin.

No. XI.—Patient H, aet 20, was admitted on 7-10-37. History of fever for 6 days. Patient was put on Ax from 8-10-37 in 1½ grs. doses twice a day. The effect of the treatment is shown in Chart XI. On 7-10-37, M.T. rings were present in the blood; on 13-10-37, only a few crescents were found; on 7-10-37, spleen was 1 finger below the costal margin; on 13-10-37, spleen was not palpable below costal margin.

CHART No. I.

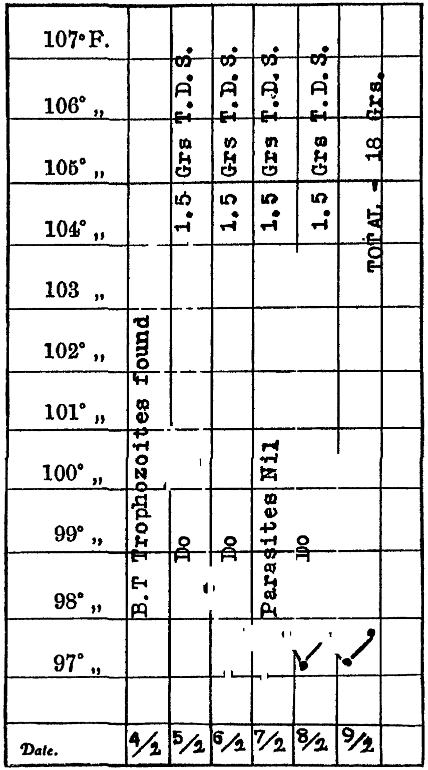
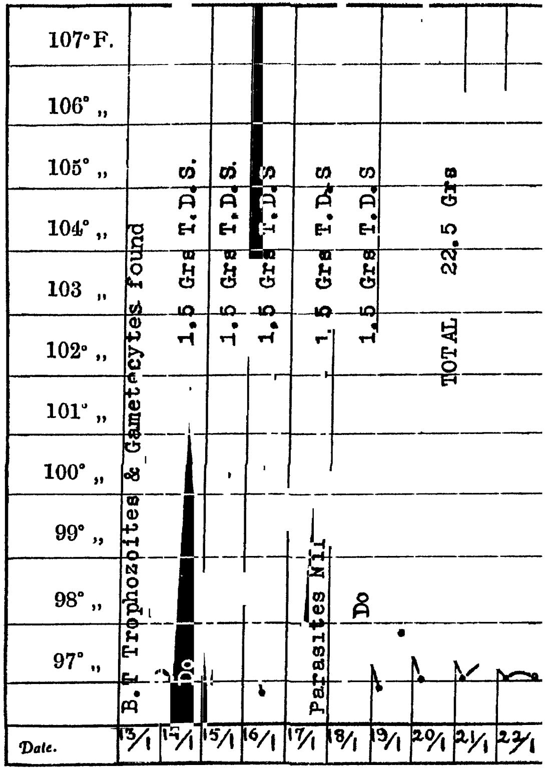


CHART No. II.



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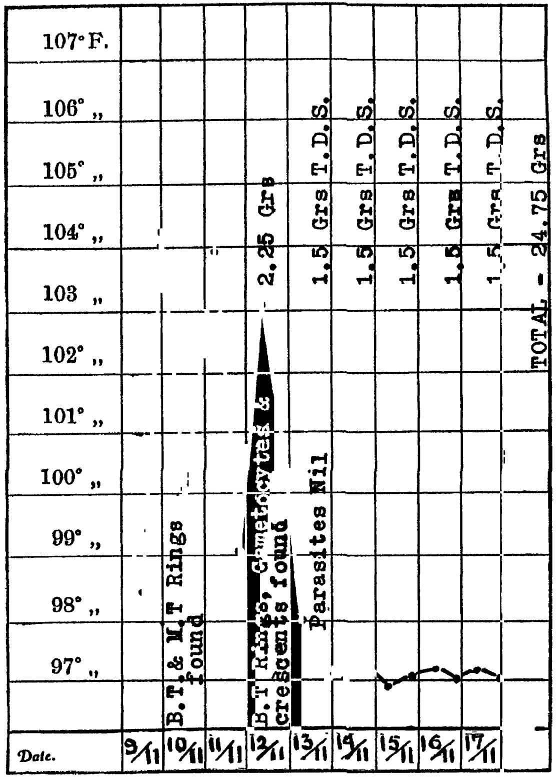

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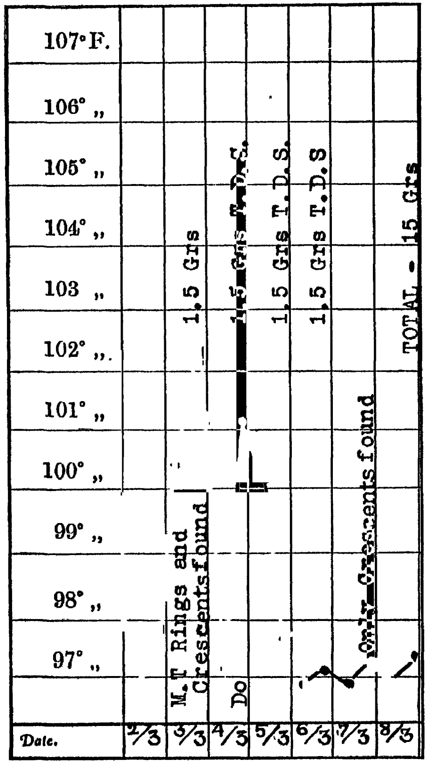
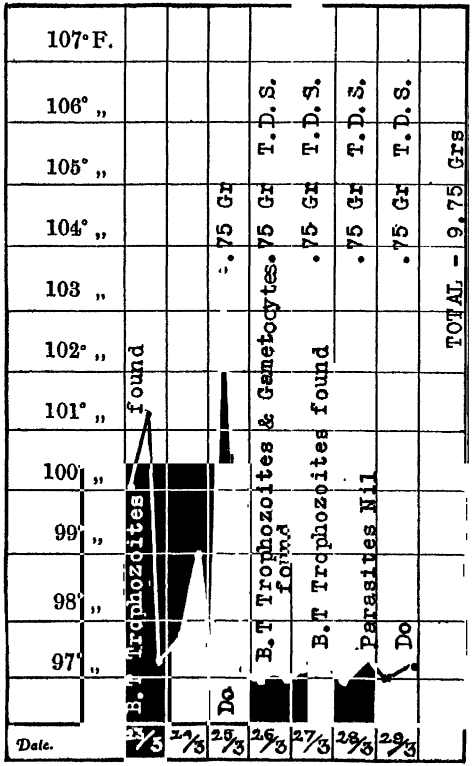


CHART No. V.



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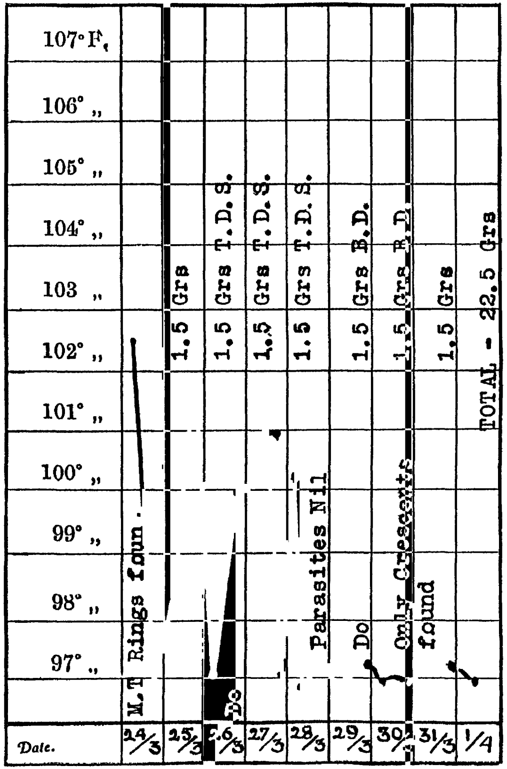


CHART No. VII.

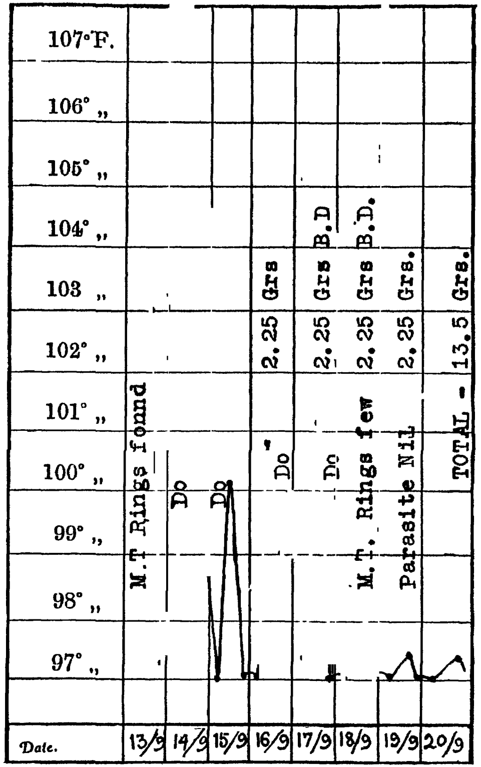


CHART No. VIII.

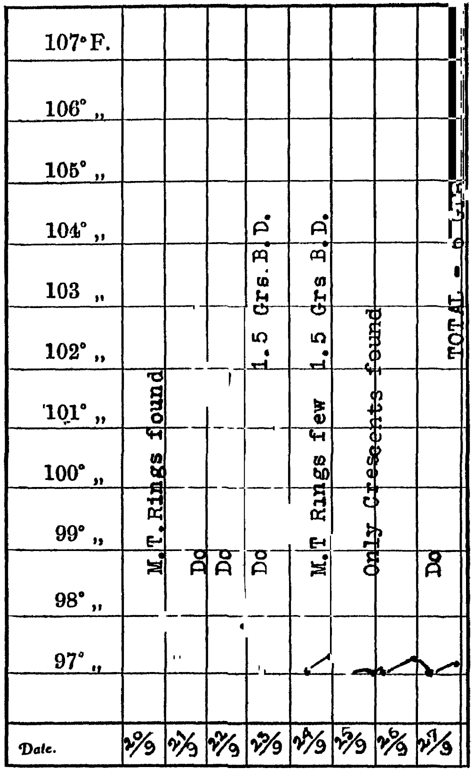
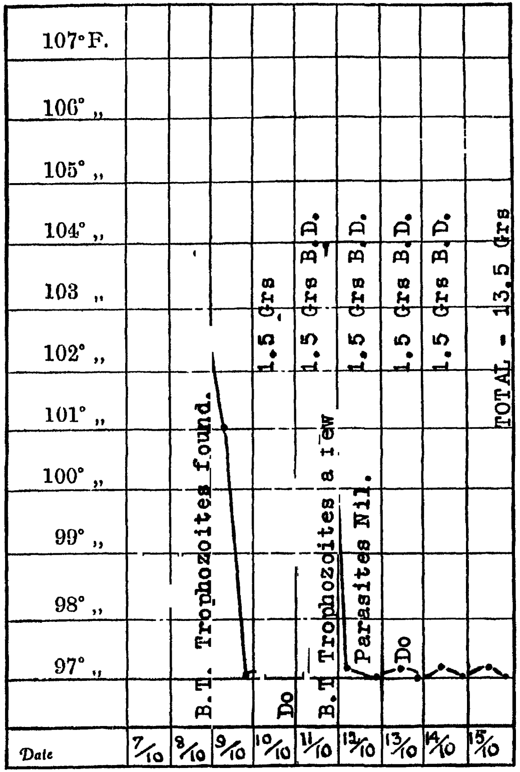


CHART No. IX.



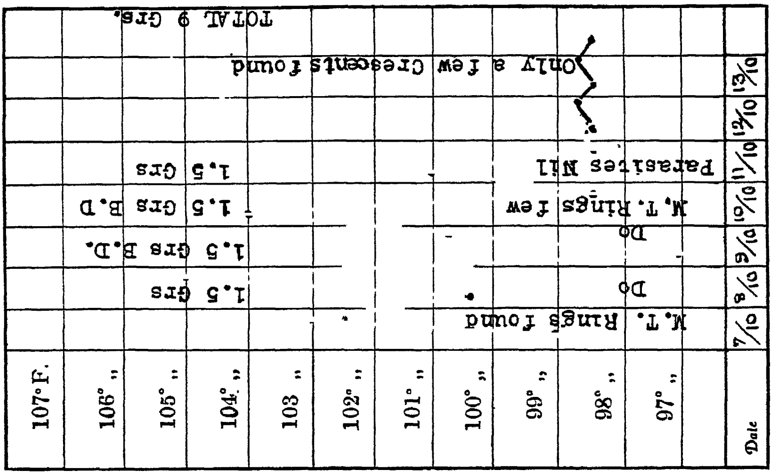


Chart No. XI.

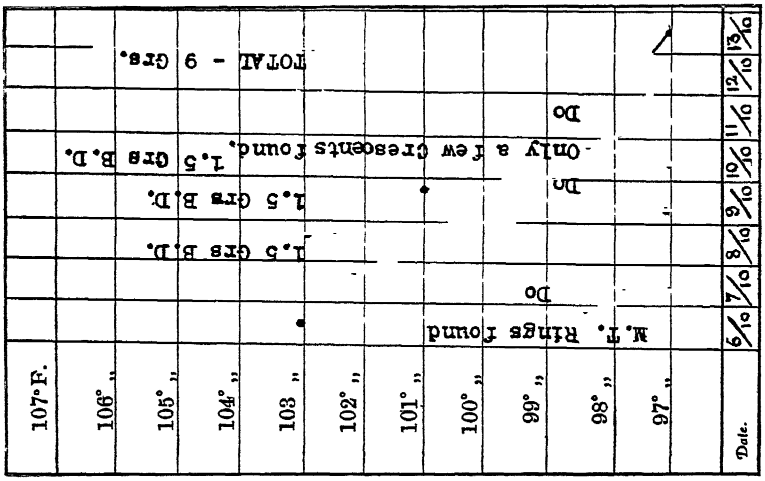


Chart No. X.

Action of Acridin X in Monkey Malaria.

The action of this drug in monkey malaria has been studied by Shortt and K. P. Menon. The following notes are taken from the paper of these authors entitled '*On Acridin X in the treatment of monkey malaria*' (Indian Science Congress Abstracts, Section of Medical Research, 1938) :—

> 'A series of experiments on Acridin X in the treatment of monkey malaria was carried out on monkeys infected with *Plasmodium knowlesi* comparing the action of the drug with that of atebrin for injection. The effect in sterilizing the peripheral blood, the cure rate, and relapse rate of the two drugs were compared. The results of the experiments showed the two drugs to be identical in their action on P. knowlesi.'

Up to now the synthetic antimalarials are mostly derived for the quinoline or acridine nucleus. As is well known, it was originally considered that the piperidine nucleus in quinine was responsible for the antimalarial properties of the latter. A few piperidine compounds have been synthesized under the author's direction, but so far they have been found to have no antimalarial properties. It may be stated, *en passant*, that one of them, namely, *piperidino-acetyl-8-amino-6-methoxy-quinoline dihydrochloride*, failed to show any antimalarial properties.

The synthesis of organic antimalarials has opened up a new vista in the treatment of malaria and will no doubt play an important point in the future campaign against the disease and its conquest.

The discoveries of effective antimalarials and leishmanocides rank among the highest triumphs of tropical medicine. Until recently, they were slumbering, like sleeping beauties, in some unfrequent corners and they now appear to have awakened as fairy gifts which synthetic chemistry bestows from time to time upon mankind.

Ladies and gentlemen, from what I have stated in my address, it will be seen that dreadful diseases like malaria and kala-azar will be conquered one day in India and thus a new chapter will be added to 'The Endless Quest'. If along with this conquest there is in India 'a proper balance between labour-saving devices and industry-increasing discoveries', and if her people 'will but decide to put in play the methods', which science today has provided for sufficient supply of food and clothing and shelter, then the health and economic problems of India, with her endless natural resources, will be solved to a great extent; then much of her unrest and unemployment will cease and she will have the opportunity of being richer, happier, healthier and freer than ever before.

SECTION OF VETERINARY RESEARCH

President :—COL. SIR ARTHUR OLVER, C.B., C.M.G.,
F.R.C.V.S., F.N.I.

Presidential Address

DEVELOPMENT OF VETERINARY WORK IN INDIA

Before proceeding with my address I must introduce our distinguished guest, Sir Fredrick Hobday, whose life-long devotion to the interest of the veterinary profession and numerous contributions to Veterinary Science are known to all of you.

To mention but one or two of Sir Fredrick's best known achievements in the field of Veterinary Science I would instance his development of the ventricle operation on horses, for the alleviation of roaring, and his research on the Anæsthesis of domesticated animals. His results were at that time a striking advance on anything which had been done before and have been of the utmost benefit particularly in canine and feline surgery.

After several years, as a Professor at the London College, Hobday left it and took up veterinary practice; but in the early days of the Great War he joined up, with characteristic enthusiasm and devotion to duty, and I was fortunate enough to have personal experience of the very valuable service which he rendered with the expeditionary force in France. Subsequently he served with distinction on the Italian Front as well and received recognition on both in the form of foreign decorations.

But his greatest achievement of all, for the benefit of the veterinary profession, has been the rebuilding of the Royal Veterinary College, which when he took it over was so dilapidated that a number of the buildings had to be propped up and the accommodation available at this, the premier veterinary college of the United Kingdom, was scandalously inadequate compared with the provision made in more far-seeing countries.

To obtain the very large sum of money which was needed, amounting with the Government contribution to a $\frac{1}{4}$ million pounds sterling, no possible source could be left untapped and in addition to his duties as Principal, Hobday devoted himself with amazing energy to securing this great sum previously almost unheard of in relation to the poorly paid veterinary profession. That he succeeded, in face of a great deal of scepticism and apathy, the magnificent college equipped with every modern convenience for veterinary work of all kinds, which has recently been opened by Their Majesties the King and Queen, bears witness and will remain a standing memorial of the great service thereby rendered to veterinary education and the veterinary profession. Hobday realized that no profession can take its proper place without proper training and made up his mind from the outset that England should have the most commodious and best equipped college in the world and we can only marvel at the success which attended his labours.

This being the Jubilee meeting of the Indian Science Congress Association, rather than address you on a scientific subject, I will try to give a brief account of the development of veterinary work in India.

As long ago as 1788 Joseph Earl published in Calcutta an English translation of a Sanskrit work on the diseases of horses, entitled Saluter and Farrier and subsequently J. P. Pigget, a Lieut. of Indian Cavalry, published, also in Calcutta, a treatise on the horses of India in which he suggested that Government should take up horse-breeding. But neither of these seems to have had any veterinary training and the need for veterinary assistance in India seems not to have been understood until after 1774 when the East India Company started horse-breeding studs. It is recorded that their operations up to that time had proved a failure and that disease was rampant. The actual record of veterinary work in this country seems to have commenced in 1799 when Veterinary Surgeons, trained at the London Veterinary College, were drafted to India for the organization of cattle and camel breeding and the establishment of studs for the breeding of cavalry horses.

William Moorcroft, who came to India in 1808, was one of these early veterinarians and appears to have been a man of outstanding ability, personality and energy. After receiving medical training at the Liverpool Infirmary, and while still a pupil he was invited to investigate an outbreak of cattle plague and his success in this matter led him to take up veterinary science as a permanent calling. With this object in view he joined the veterinary school at Lyons, in March 1790, and after qualification returned to England in 1792 to take up veterinary practice in London. Sixteen years later, in order that he might take up an appointment in India which had been offered him, he gave up the extensive veterinary practice which he had built up in the meantime and, in 1808, was appointed, by the East India Company, Superintendent of their Bengal stud which was located at Pusa in North Bihar. It is recorded that by improved management he reduced losses by 90 per cent and that among other things he was responsible for oats being cultivated in India for the first time.

While holding this appointment Moorcroft, with a view to improving the breed of Remounts for India, carried out two extensive journeys in Central Asia and during the course of the second appears to have been murdered. In Bokhara he had obtained the horses he was in search of, both mares and sires, and had started on his return journey to India, but he unfortunately turned aside to visit Balkh, a place said to contain the finest horses in the world and was never seen again. His property was plundered and his copious Journals were lost for years.

The main object of his journey was therefore not achieved but his journals afterwards proved a mine of information on a great variety of subjects and it is evident that Moorcroft did a great deal to establish the value of veterinary knowledge in horse-breeding and in the care and management of breeding studs. Among other things he published a comprehensive pamphlet of directions for the use of Company officers, and was the first to introduce machine-made shoes. He also wrote a small book on shoeing and appears to have been quite familiar with the symptoms and progress of such conditions as Navicular disease.

Indeed there is a record in the Calcutta Journal of March 1819, that he performed the operation of neurectomy for that disease. After trying the arteries to reduce the inflammation, without benefit, he divided the nerves and removed a portion with the result that the lameness disappeared. There is also in existence a letter of Moorcroft's in which he describes the clinical feature of Glanders and how to stay infection. In this letter he pointed out that Strangles might be confused with Glanders, and drew attention to the great frequency of generalized Strangles in Asia than in Europe. He knew that Farcy and Glanders were due to an identical poison and that the Glanders discharge, when dried, retains its virulence for months. He considered Bursati to be in all probability infectious and stated that flies might carry infection.

In the Journal kept by Moorcroft, in which the observations made during his travels were recorded, various matters of veterinary interest were found. Amongst others he warned the Government of India against a fatal disease met with in the Punjab which, from the postmortem appearances described by him, has since been identified as Anthrax. He also mentioned a plant growing in Western Tibet, known as Prangos, which was believed to prevent or cure fluke disease in sheep and stated that in Afghanistan a course of green feeding with ' Shufteed ' was given to get rid of parasites. His interests were so wide that among other things he sent home a mass of valuable information, on a variety of matters connected with agriculture, and he is credited with having placed the Kashmir shawl industry on a sound footing. He described a breed of mountain sheep with wonderful wool and gave an account of a new species of the genus *Equus* ; which was neither horse, ass, nor mule and which he thought might have been the Onager of Pliny. He also described the method of training horses which was adopted in Central Asia prior to a raid. The system consisted in a gradual increase of work with no bulky food; the diet being mainly barley with water given once a day only. When the horse was fit, it was considered that its fæces put in a clean dry cloth and squeezed should not leave a stain. Thus Moorcroft must have been far ahead of his time in many ways and it is recorded that he was a short, slight, quick-tempered man of high intelligence and wide interests. His tomb is in Lahore.

The earliest available official reference to veterinary work in India appears to be a general order of the Bengal Army, dated 8th of April 1793, in which it is stated that upon the appearance of a supposed infectious disease among horses, the affected would be removed from the Cantonment and the matter reported to the Officer Commanding the Station, 'who will order the animals to be inspected by persons who may be judged capable of distinguishing the disorders of horses'. At that time there was not a single qualified veterinarian in India and only two in England: Sainbel and Moorcroft. In 1799, five veterinary officers, trained at the Veterinary College, London, proceeded to India, but two of these were soon invalided home and little is known of their work. It appears that these veterinary officers were attached to British Regiments serving in India.

From 1826, after Moorcroft's death had been confirmed, until 1832, the management of horse-breeding establishments was again under the control of Infantry and Cavalry officers but in 1832, in consequence of terrible losses from disease, the East India Company insisted upon Veterinary Surgeons forming part of the staff of the various depots and J. T. Hodgson appears to have been one of these and a man of considerable influence. From the Government horse-breeding stud at Hissar, in the Punjab, he was appointed to the Governor-General's Body-Guard at Calcutta, in 1821, and was directed to train Assistant Apothecaries—half-caste Indians—as Veterinary Surgeons for the troops of the Bengal Army. When qualified, these men were to be appointed Sub-Assistant Veterinary Surgeons with the pay and allowances of an Apothecary. But in 1822, Hodgson warned the Bengal authorities that their scheme would not work, so the project came to nothing and in 1823 only three Sub-Assistant Veterinary Surgeons were borne on the establishment of the Army. In August of that year, Hodgson submitted to the Government of India a scheme for the creation of an organized veterinary service. His proposals were that the East India Company should provide a professor at the London College to deliver a course of lectures to candidates for the Indian Service on the breeding, rearing, management and diseases of horses, cattle and camels and on shoeing, so that prior to proceeding to India, veterinarians should have expert knowledge of these matters. To these lectures the Company's civil, military and medical servants were to be admitted, should they desire to attend, and Hodgson considered this preferable to the arrangement made by Coleman to give lectures on veterinary matters to cadets at Woolwich. In regard to the organization of veterinary services in India, Hodgson proposed an officer on the general staff of the Army in India, as principal Veterinary Surgeon; one veterinary officer each to the forces in the Presidencies of Bengal, Madras and Bombay and an administrative officer to each Division, in addition to executive officers for Brigades of Horse Artillery, Regiments, Cavalry, breeding studs and other Departments of the Army provided with animals. He made provision for sickness and deaths, by having a certain number of supernumerary officers available in India, and drew up tables of pay and allowances; rules regarding promotion, leave and pensions, and formulated a set of veterinary regulations, but his proposals appear never to have been acted upon.

In 1827, twelve Veterinary Surgeons came out to India and in 1828 a further 13, while subsequently, veterinarians were supplied as casualties occurred. The establishment in the three Presidencies in 1833 was 31. Recruits appear to have been selected by Mr. John Field of the 2nd Life Guards. They were intended for the care of army animals but the Veterinary Department of India remained without an official head or a single administrative officer for forty years. Thus the early veterinary work done in India appears to have been done by veterinary officers of British and Indian Cavalry Regiments and much valuable information was undoubtedly obtained regarding the diseases of domesticated animals in this country. For example in 1881, Griffith Evans, of the Army Veterinary Department, for the first time demonstrated a large flagellated organism—now known as *Trypanosoma evansi*—in the blood of horses and camels affected with Surra, a previously little understood but well-known fatal disease of all classes of domesticated animals in India. Evans was born in Wales in 1835 and entered the Army Veterinary Service in 1860. He proceeded to Canada in 1861, with the Royal Artillery and while at Montreal graduated in medicine at the McGill University. His scientific enthusiasm was widely known and was referred to by Sir William Osler, Regius Professor of Medicine at Oxford, but Evans' report of his discovery was referred to the Sanitary Commission to the Government of India and was not accepted, while his findings were derided in certain quarters. They have, however, since proved to be an epoch-making advance in the knowledge of protozoan disease and have been of immense benefit to the human race as well as to their livestock.

The next important event in the advance of veterinary work in India was the recommendation by Hallen of the formation of an Indian Civil Veterinary Department with schools for the training of students. Hallen entered the service of the East

India Company in 1850, joining the Bombay Veterinary Service and, in 1862, became Inspecting Veterinary Surgeon of the Bombay Army. He organized the veterinary service of that force and established an Army Veterinary School at Poona. In 1863 he was made Superintendent of the Stud Department of Bombay and from 1863 to 1868 was head of the Veterinary Service in the Abyssinian War. In 1869 his services were asked for by the Government of India, in connection with Cattle Plague and he became President of the Commission which sat until 1872. From 1872 to 1876 he was one of the Commissioners charged with the breaking up of the old Indian studs and he organized the horse-breeding operations of India, of which he was Superintendent. Finally, in 1892 he became Inspector-General of the Civil Veterinary Department of India. He was awarded the C.I.E.

The next personality of outstanding influence on veterinary developments in India was Col. Pease, who by his energy and ability raised the Lahore School from very humble beginnings to an outstanding position. Among other activities, he translated textbooks into Urdu, for the use of students, and lectured in that language. He conceived the formation of an Imperial Bacteriological Laboratory; originated and edited the Journal of Tropical Veterinary Science—with other enthusiasts among whom the names of J. H. Steel and F. Smith (afterwards Maj. Genl. Sir F. Smith) should be mentioned—and appears to have been the first to diagnose the existence of Dourine in India. He also did valuable work on Surra and, while actively engaged in the cattle survey of India, published a very valuable series of books on the breeds of Indian cattle.

The first veterinary school opened in India appears to have been that at Babugarh which was opened in 1874, a similar one being established about the same time at Rangoon. The Babugarh school was afterwards transferred to Lahore and formed the nucleus of the present college. Subsequently veterinary colleges were established at Bombay, Calcutta, Madras and at Ajmer (Merwara) but this last was afterwards closed and the staff merged in that of the Lahore Veterinary College. Later a Government Veterinary College was established at Patna and it is worthy of note that the colleges at Calcutta and Bombay were established as a result of private donations of large sums of money; in the first case by a wealthy zamindar and in the second by a well-known Parsi philanthropist.

In 1881 the Government of India offered a prize worth Rs.200 for the best original paper on the horse disease commonly known as Kumari or Paraplegia and in 1883, with a view to encouraging the study of Veterinary Science, the Governor of Bengal offered two prizes, one of £50 and the other of £20; open to Army holders of agricultural scholarships from Bengal, who had studied at the Royal Agricultural College, Cirencester.

Thus the value of veterinary work gradually became established but even today the position of disease control in India is peculiar in that there are no veterinary practitioners, except a few in Calcutta and other big cities, and stock-owners are almost entirely dependent on Government veterinary services for veterinary aid. It is therefore incumbent upon Governments to organize and maintain suitable provincial veterinary services ; for the control of contagious disease and to provide veterinary aid and assistance in the proper care and management of live-stock. In the early days, these services were mostly under the Director of Land Records and at that time there were no veterinary colleges in India. The obvious step for the advancement of Veterinary Science was therefore to establish suitable colleges or schools for the training of veterinarians in India and when graduates became available, provincial veterinary services were gradually organized ; by officers transferred from the Army Veterinary Department to take charge of the newly formed Civil Veterinary Departments. Veterinary hospitals and dispensaries were opened at suitable centres and the work of the Departments has gradually been developed and extended as more graduates have become available.

In most provinces, superior veterinary services were formed, officered by veterinarians with the M.R.C.V.S. or equivalent qualification and, in addition, subordinate services officered by graduates of Indian veterinary colleges.

An Imperial Veterinary Service was also formed but recruitment to this service ceased in 1924 and the number of fully qualified veterinarians in India remains far too small for the bare requirements of such a huge country. For example, the Royal Commission on Agriculture in India recommended 300 officers and 6,000 subordinate staff for British India but in 1936-37 the strength was only 109 and 1,646 respectively. Various proposals have been put forward for the establishment of an All-India Veterinary College, to train up to the M.R.C.V.S. standard, and the matter is now being dealt with. But as no such course was available in the country, the Government of India and Provincial Governments decided, in 1920, to give a limited number of scholarships to enable students to take the M.R.C.V.S. qualification in the United Kingdom. In addition a number of students have obtained this qualification at their own expense.

The scope for development of veterinary work in India is however immense, not only in the control and treatment of contagious and enzootic disease, which is rife, but also in such animal husbandry matters as systematic control of breeding operations, and inoculation of improved stock against diseases combined with organized castration, at a suitable age, of inferior males not required as sires.

Owing to the general lack of wealthy land-owners who take a genuine interest in livestock improvement this work is of the greatest importance and recently the Government of India has recommended that all animal husbandry work should be in the hands of Provincial and State Animal Husbandry Departments, based on the existing Provincial Veterinary Departments. At present this work is partly in the hands of Veterinary Departments and partly Agricultural Departments but it is clearly essential that veterinary graduates from Indian colleges should in any case be thoroughly grounded in animal husbandry subjects; particularly as there hardly exists in India an educated class of scientific stock breeders from which young men with hereditary knowledge and interest in livestock could be drawn for the control of breeding operations. Indians who have received veterinary training have already proved their superior value in such work and with a view to increasing existing facilities, particularly for training in animal husbandry, it has recently been recommended that a dairy should be maintained at every veterinary college in India and that the I.D.D. course should be open to veterinary graduates, after a reduced course of study in addition to what is given in their graduate course.

One of the most important steps ever taken for the development of veterinary work in India was the appointment in 1891 of an Imperial Bacteriologist, whose headquarters were in the first instance at Poona. After two years, it was decided to instal this officer at a Veterinary Research Laboratory at Muktesar, in the Kumaon Hills, 'for the investigation of diseases of domesticated animals in all provinces in India'. The first Imperial Bacteriologist was Lingard, a medical man, who among other things discovered the specific affinity of arsenic for the parasite of Surra: a discovery which has led to results of the greatest importance to the human race. From the day of its establishment in the Kumaon Hills, where it was free to carry on systematic research in animal diseases of all kinds, the Muktesar Institute has built up a world reputation and has done an immense amount of work of the greatest value to Indian stock owners. The advances made by Veterinary Science in India during the past 25 years have been fully dealt with by Mr. Ware in a paper specially prepared for this meeting and I will not attempt to discuss them in detail but there are a few general remarks in regard to the control and treatment of disease in this country which I would like to make. The most important advance from the point of view of owners of livestock has undoubtedly been the great step forward which has been made in the control of Rinderpest due to the general adoption of a system of vaccination with goat virus. This method has been evolved as a result of the continuous research and investigation, which has been carried on at Muktesar for many years, into all matters relating to Rinderpest control. In the course of this work Dr. J. T. Edwards produced a goat virus of fixed and reduced virulence for the ox and from this beginning a method of vaccination has been evolved there, which has proved highly successful and economical in controlling outbreaks of Rinderpest among plains cattle, without the use of anti-Rinderpest serum. This discovery has made it possible to control outbreaks at fractional cost, compared with the cost of the serum simultaneous or serum alone methods, and at the same time to confer lasting immunity which, so far, has proved to be solid one, for as long as it has been possible to test it, i.e. up to more than 3 years. For the poor cultivator of India, whose very life depends on his cattle, this is an immense boon and the fact of Cattle Plague being so comparatively easily and cheaply controllable has enabled Provincial Veterinary Departments to devote more attention to other fatal diseases such as Hæmorrhagic Septicaemia, Black quarter and Anthrax. These still take a heavy toll of the cattle of India but are now better under control by means of biological products, evolved for the most part in other countries, and during the past 5 or 6 years great advance has been made in the treatment of Surra as a result of research at Muktesar and systematic investigation carried out in the Punjab and other provinces. Great advance has also been made in the study and control of various forms of Schistosomiasis, of which nasal granuloma is an important and often fatal manifestation, over large areas particularly in S. India, and in the study of lesions of the skin and subcutaneous tissue due to larval forms of Filaria. Progress has also been made in the study and treatment of diseases due to the great variety of Piroplasmal organisms which are of great economic importance to India. The study of the protozoa pathogenic to livestock in India is however an immense subject, the fringe of which has hardly been touched, and far more requires to be done to obtain precise information regarding these organisms and the helminths by which livestock of all kinds are parasitized to an enormous extent throughout India.

The systematic disease investigation now carried on in all provinces and some of the large Indian States has moreover brought to light a number of disease conditions, due to malnutrition and other causes which were previously not understood, and has enabled steady advance to be made in the study and control of a great variety of diseases of stock of all kinds.

But the field for scientific veterinary work in India is immense and the fully trained workers are few. Meanwhile the poor ryot has to suffer continuous and heavy loss from a great number of causes which, with more and better trained staff and more adequate provision for combined veterinary and animal husbandry activities, could easily be brought under better control.

Some research is carried on at Indian veterinary colleges, notably at Lahore and Madras, and during the past five years provision has been made by the Imperial Council of Agricultural Research for systematic investigation of the disease of livestock, in provinces and States throughout India, by the provision of veterinary investigation officers paid by the Imperial Council of Agricultural Research. Though paid out of funds provided by the Imperial Council of Agricultural Research these officers are under the direct control of the Director of Veterinary Services of the province or State concerned and work in collaboration with the Muktesar Research Institute, or a veterinary college where suitable facilities for research exist.

There are in all five veterinary colleges in India, the longest established being the Punjab Veterinary College at Lahore which was originally founded as an elementary school by Col. J. H. B. Hallen at the Remount Depot, Babugarh. This Remount Depot was, however, abolished soon afterwards and in 1882 the veterinary school was transferred to Lahore with Col. Kettlewell as the first Principal. In spite of its humble beginnings and very inadequate accommodation and equipment, this school has continued to make steady progress and has established its great value to livestock owners. The successive Principals of this college have been Col. G. Kettlewell (1882–90), Col. J. Nunn (1890–97), Col. H. T. Pease (1897–1907 and 1912–19), Col. A. Smith (1907–12), Col. G. K. Walker (1919–26) and Mr. W. Taylor who at present holds this post.

The course of instruction was originally given in the vernacular and was of two years' duration but, in 1900, the period of the course was raised to three years and the name of the institution was changed to 'The Punjab Veterinary College'. In 1905, the veterinary school which had previously been established at Ajmer was abolished and its teaching staff was absorbed by the Punjab Veterinary College while in 1919 under Col. Pease new and commodious buildings and accommodation were provided which made the Lahore College an exceptionally well-equipped veterinary college, for training in all branches of Veterinary Science. At that time the course was still a three-year one but in 1919, during Col. Walker's principalship, four-year course in English was instituted and the Intermediate Examination of the Punjab University or equivalent test was made the educational standard for admission to the college.

In August 1886, a veterinary college was opened at Bombay in the S.P.C.A. Buildings which, in 1883, had been presented by Bai Sakarbai Dinshaw Petit, a well-known Parsee philanthropist of Bombay city. The hospital buildings were handed over to Government and some additional buildings required for the use of the college were built afterwards.

The course of study at this college has been a three-year course in English since its foundation but the standard has varied considerably. J. H. Steel, the first Principal, originally aimed at obtaining recognition by the Royal College of Veterinary Surgeons and, with this object in view, drew up a syllabus for the advanced course which was brought into force in 1890. But, Steel very unfortunately died, in January 1891, and the syllabus drawn up by him, being considered too advanced, was modified and simplified. In 1900, a Conference of Principals of various Indian veterinary colleges and schools was held at Ambala and, as a result of this Conference, the written examinations at the Bombay Veterinary College were discontinued and the course was simplified and made uniform with the courses at that time given at the Bengal and Lahore colleges, an oral test being the only test then applied. A simplified curriculum thus became the basis of all veterinary education in India and at first non-Matriculate students were admitted, but later the educational standard was raised to Matriculation at all veterinary colleges. This standard is still the standard of admission to the Bombay Veterinary College and the course is still a three-year one, in English. The Principals of this college from its inception have been Mr. J. H. Steel (1886–1891), Lt.-Col. James Brodie Mills (1892–1908), Major Frank Josler (1909–1910), Mr. K. Hewlett (1911–1930) and Mr. V. R. Phadke who at present holds this post.

The establishment of a veterinary college in Calcutta was first recommended by the Cattle Plague Commissioners, on the completion of their duties in 1871, and in the interim repeated proposals were made by the Inspecting Veterinary Surgeon, J. H. B. Hallen, to provide such a college. No action was, however, taken until 1891, when Babu Sheo Baksh Bagla generously gave Rs.30,000 to Government in aid of the project and offered 7¼ bighas of land for the site. Sir Dinshaw Monochjee Petit also promised a donation of Rs.25,000 for the establishment of the hospital. The school was opened in January 1894 and was subsequently raised to the status of a college in 1898. The first Principal was Col. F. Raymond (1898–1912) followed by Col. A. Smith (1913–1920) and Mr. A. D. MacGregor, the present Principal. The course of training at this college is a three-year course in English.

As long ago as 1882, veterinary courses appear to have been given in Madras, at the School of Agriculture at Saidapet, by Veterinary Surgeon—James Mills, A.V.D. The curriculum at that time embraced among other subjects, veterinary medicine and surgery and the course extended to three years. The present Madras College was opened in 1904 and has been extended from time to time by the provision of increased laboratory accommodation and facilities for carrying on research and the manufacture of biological products ; while recently a small dairy has been established in connection with this college, with a view to providing increased facilities for the instruction of students in the care and management of animals in health.

The course is a three-year one in English and recently the college has become affiliated to the Madras University by which, after a short course of extra instruction, the degree of B.Sc. (Veterinary) is granted to successful candidates. The Principals of this college have been Major W. D. Gunn (1904–1908), Mr. D. A. D. Aitchison (1909–1925), Mr. F. Ware (1925–1927), Mr. P. T. Saunders (1927–30), and Mr. T. J. Hurley who at present holds this post.

In 1930 a veterinary college was opened at Patna. The establishment of this college was the work of Mr. D. Quinlan, the then D.V.S., Bihar and Orissa, and it is fortunate that he had the vision to establish an extensive farm at which cattle breeding and dairying can be carried on and made use of for the grounding of veterinary students in the care and management of cattle; which is so essential to the training of veterinary students in India. The course is a three-year one in English and the minimum educational qualification laid down for admission to the college is Matriculation. The Principal of this college since its institution has been Mr. R. T. Davis.

Thus there are five veterinary colleges still in existence in India, but the staff and facilities provided for veterinary training in this huge country are still very inadequate, even for training up to the comparatively low standards which are accepted as sufficient for veterinary graduation.

The provision of a central veterinary college, to provide training up to the M.R.C.V.S. standard and in research, in conjunction with the Veterinary Research Institutes of Izatnagar and Muktesar, is being taken up by the Government of India but more fully qualified staff and better facilities for research and animal husbandry training are urgently needed at most of the existing colleges; to enable them to train up to modern standards and to carry out such diagnostic work and research as can suitably be undertaken at such colleges.

This has become all the more necessary since the provision by the Imperial Council of Agricultural Research of Veterinary Investigating Staff, in each major province and certain States, which it is now proposed to extend and develop for the systematic investigation of disease problems all over the country which is so urgently needed. This investigation work has increased the demand for co-ordinated veterinary research.

The field for such work is unlimited and up to the present almost untouched but, for such work, high standards of education and veterinary training are needed and I appeal to Indian veterinary institutions of all kinds to aim constantly at producing veterinarians fully equipped for such work and able to take the predominant place in animal husbandry work for which their training under Indian conditions and daily experience should form the best background. The low standards of education and training which are now commonly accepted for Indian veterinary graduates will never provide the highly trained veterinary services which are essential for the proper study and control of disease and for systematic improvement of livestock in this sub-continent and if the veterinary profession aspires to take its proper place and to justify higher scales of pay it will have to insist on raising its standards, at least as regards selected students, to the levels which have now been adopted in all progressive countries. Low standard of education and training can only mean low status and low scales of pay.

SECTION OF PHYSIOLOGY

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Presidential Address

THE PHYSIOLOGY OF THE INDIVIDUAL IN THE TROPICS

Introduction

I consider it my duty first of all to thank you for the great honour you have done me in asking me to be the President of the Section of Physiology during this, the Jubilee Session of the Indian Science Congress. When the invitation was first extended to me, I had considerable hesitation in accepting it. As my labours have been principally confined to the domains of pharmacology and tropical medicine, my first reaction was to consider whether I would be justified in assuming the responsibilities of guiding the deliberations of the group of scientists who have assembled here to-day. On further consideration I persuaded myself to accept the honour, for physiology after all is the science of function, whether it is studied in broad outlines as dealing with the mechanism of action or as the physico-chemical mechanisms leading up to this action. Disease means a lack of integration or balance of the normal body processes (disintegration) or an unusual functioning of tissues (dysfunction) which may be the result of accident, hereditary weakness or parasitic organisms. It is not correct to designate it as disordered function (malfunction) as is sometimes done; the unusual functioning is physiological and perhaps the best for the organism under unusual conditions. Medicine aims at prevention or cure of 'disease' and it is, therefore, nothing more than trained and organised application of the principles of physiology. Pharmacology, the science dealing with the action and uses of drugs on tissues, is inseparable from physiology. It is, in fact, the climax of physiology and pathology. Both pharmacology and medicine therefore are not far removed from physiology and if one who has been engaged in the field of pharmacology and tropical medicine for about a quarter of a century accepts such an honour and assumes the rôle of a physiologist, he may be pardoned.

'Normal' individual a relative term.

Though physiology in its widest sense signifies the study of the phenomena presented by all living organisms, its chief interest is centred round the body of man. It should therefore be the objective of human physiology to study the so-called 'normal' human individual, since it provides an essential base line for the study of disease. Unfortunately, however, in this particular branch, 'physiology' in spite of all its developments has made but little progress in recent years. The definition of 'normal', and the criteria of what constitutes the normal, are still open question. There has been a tendency among physiologists to lay stress on individual organs and tissues,—'on single bricks' composing the edifice —and not on the individual as a whole. As the human individual cannot exist uninfluenced by his external environment and as the environment is variable, the question of normality of the individual becomes relative, and has to be studied under the varying conditions of the altered and continually altering environments to which the individual must necessarily be subjected in different parts of the globe. In choosing the subject of '*The physiology of the Individual in the Tropics*', I had two objects in view. In the first place, I was anxious to select a subject which would be of interest to physiologists as well as to the medical profession in India; in the second place, I chose it as a subject which is of fundamental importance, but which has suffered from comparative neglect in modern medical thought.

THE INDIVIDUAL AND HIS ENVIRONMENT

Historical.

The study of the individual in relation to his environment has recently engaged the attention of many a physiologist and clinician though the problem is by no means a new one. In the earliest days of medicine in India centuries before the Christian era, the Hindu physician *Charaka* drew attention to the effects of different 'airs' and places on mankind. He prescribed special diets for particular seasons of the year, recommending one type of food for the summer and another for the winter. In the early dawn of Greek medicine Hippocrates recognised not only the significance of a 'change of winds' but also its physiological implications. After considering the effects on the embryo and the adult, he concluded that the races of mankind and types of animals were altered, as a result of the environment—and in this the 'airs, waters, and places' played a part. The Hippocratic recognition of the association between meteorological conditions (airs) and disease came down through the middle ages and practically every writer on medicine and physiology from the 17th to the 19th century stressed in different ways

Discovery of bacteriology and its influence on physiological studies.

the 'Integration of the macrocosmos (environment) with the microcosmos' (the human organism). The interest in this subject waned in the last quarter of the 19th century when the science of bacteriology made its beginning through the pioneer researches of Pasteur, Lister and others. In the study of diseases, emphasis was laid more on the invading parasite than on the invaded individual. With the advent of the science of immunology, serotherapy and chemotherapy, the importance of environmental influence receded more and more into the background. Whilst physiologists studied the changes produced in the system by alteration in temperature, bacteriologists tended in their first enthusiasm to disregard the physiological fluctuations and attempted to attribute every disease process to specific parasites.

The reaction to environment.

Though the interest of medicine at present is chiefly centred and perhaps rightly, on infectious diseases, the study of environmental conditions is none the less important. Let us consider how the individual reacts to his surroundings. Two methods have been devised by the organism to meet the forces of its environment. It may seek to lessen the impact and to meet the shock by increasing the resistance, in an endeavour to prevent disturbances of its equilibrium. This is usually effected by diminishing the consumption of energy or in other words, the organism becomes *less reactive.* This phenomenon of attempting to shield itself against invasion is exemplifed in spore formation and in the various forms of encystment of lower organisms. In the higher organisms, the same reaction finds expression in the mechanism of hibernation, in the deposition of subcutaneous fat and in the development of the epidermis. The other alternative is that the organism bcomes *more reactive* and instead of resisting any force disturbing its equilibrium, seeks to attune its mechanisms of equilibration to such a degree that they swing in a rhythm with the environmental force. This is seen in the development of special mechanisms for the rapid mobilization of reserves, in the unusual acuity of receptors and not infrequently, in the formation of special sense organs. Man, after all, is a living organism existing in his own particular environment and, being endowed like all living beings with powers of adaptation, he reacts to it in such ways as to produce, if possible within himself, ideal conditions for living under varying environments. This adjustment must necessarily involve fundamental physiological changes in the organism, and probably also in its powers of resistance to disease. The history of man is not inaptly described as 'an endeavour first to adjust himself to his environment and later to control that environment itself.'

The mechanisms designed to meet the environmental demands and the selection by the organism of different methods for adaptation are manifold. We will consider them in more detail later. It is important to emphasize here that it is not enough to understand any one reaction to a single well-defined change in environment; the repercussions on other reactions must also be determined and the degree to which they affect the capacity of the individual to react to further environmental changes of a different type. Such knowledge is essential if the organism is to be understood as a unit. The problem is naturally complicated and raises many interesting enquiries.

THE INDIVIDUAL AND HIS PHYSIOLOGICAL EQUILIBRIUM

The external environment with the effects of which we are concerned is not in reality the one in which the body cells live. As is well known, though the external environment varies greatly, the internal one remains remarkably constant and this is achieved firstly, by certain physical and chemical factors inherent in the saline fluids which constitute the internal environment—the '*milieu interne*' of Claude Bernard—secondly, by certain bodily reactions designed to prevent abnormality. An outstanding example is the constant neutrality of the fluids which bathe the body cells where even a slight increase in the hydrogen-ion-concentration from 0·000,000,05 $(10^{-7} \times 5N)$ to 0·000,000,1N $(10^{-6}N)$ might produce a serious dislocation of the vital processes. To counteract any such disturbances, there is always an effort on the part of the organism to oppose any tendency to change. This is best seen in the rapid breathing associated with all forms of muscular exercise. A contracting muscle needs proportionately more oxygen than a quiescent one; this increased oxygen usage implies an increased blood supply which again involves an augmented blood flow through the lungs and consequent increased ventilation. Similarly, the response to a rise of body temperature sets in motion simultaneously a number of complex reactions which tend to oppose any threatened alteration.

Physiological stability is a dynamic not a static equilibrium.

The apparent physiological stability of a living being which is suggested by the constancy of such characteristics as heart rate at rest, body temperature, blood sugar level, reaction of the blood, blood volume, blood pressure and composition of alveolar air, is not due to a static condition, but is only made possible by the lability and close correlation of dynamic forces which are constantly being adjusted in response to nervous, chemical or physical stimuli arising within or at the surfaces of the body. The equilibrium thus attained is therefore of an oscillatory type and is the resultant of the interplay of unstable and variable functional activities which are constantly operating in the body. Thus, the carbon dioxide content of alveolar air is remarkably constant in any individual and is controlled by the depth of respiration, which in turn is regulated by the carbon dioxide content of arterial blood; the respiratory centre is so sensitive that it will respond to changes which cannot be easily measured by chemical or physical methods. This high degree of sensitivity maintains the equilibrium without demonstrable oscillation but the oscillatory nature of the equilibrium may be unmasked and become recognizable in certain diseases as Cheyne Stokes or other types of periodic breathing. The temperature of the body is maintained fairly constant in health, despite variations in external temperature and activity, but during illness or during recovery from illness there may be a lack of sensitivity or some degree of failure of the regulating mechanism and the least exertion may cause an abnormal rise of temperature producing profuse sweating with a temporary fall of temperature below normal. Similar examples showing the oscillatory nature of physiological equilibrium might be taken from circulatory adjustments, muscular co-ordination or from the regulation of blood-sugar level.

The range of reactivity and the limits of adaptability.

Interference with or destruction of these compensatory mechanisms will reduce the chance of recovery from accidents or diseases in which their activities are required to counteract the disturbance. A given compensatory mechanism may be adequate to maintain, under resting conditions, a physiological equilibrium within normal limits, so that the effect is not recognized until the mechanism is subjected to some stress. Thus, two individuals may have the same heart rate under the same resting conditions, but if the vagal impulses in both are eliminated by the injection of atropine, it may be found that the heart rate of one considerably exceeds that of the other. The heart rate is controlled by two opposing forces, one from the vagus and the other from the sympathetic, and although the net result of these may be the same in both before the injection of atropine, yet in the one a greater amount of nervous stimulation takes place than in the other. Again the fasting blood sugar level in two individuals may be identical and yet the injection of the same amount of adrenalin into each may cause in the one a much greater rise in blood sugar than in the other. Insulin will be less effective in the former than in the latter, suggesting that the self-adjusting mechanism in the one case is 'set' at a different level from that in the other, although the controlling factors in each case are so balanced that the equilibrium points are the same. Neither heart rate nor blood sugar level *per se* therefore gives any clue to the reserve powers of the complex systems which control these physiological characteristics. Hence the test of physiological normality is relative and is not solely or even mainly the equilibrium point of the various compensatory systems. In fact the extent to which these systems will respond, when brought into play by adverse changes in the environment of the individual, and the degree of their response are measures of the organism's reserve capacity or power of adaptation. On this reserve power depends the success of the individual in his adaptation or acclimatization to changed surroundings and environments.

ENVIRONMENT AND THE MECHANISM OF ADAPTATION

Physiological factors in adaptation.

Adaptation has been aptly defined as the continuous adjustment of internal relations to external relations. This ability to respond actively to changes in environment is an essential characteristic of any organism. The range of environmental adaptation of even the most primitive cell is relatively wide, although the mechanism of response may be simple ; but as we advance in the scale of animal life, the range of adaptation becomes even greater as the mechanism and the means of adjustment become more complex. Thus the single-cell organism existing in a relatively stable fluid environment needs only direct adjustment to the environment and this adjustment must of necessity be a '*chemical*' one. This is exemplified in the behaviour of the protoplasm of the *myxomycetes* which, when placed on a piece of blotting paper, will crawl towards an infusion of dead leaves or away from a solution of quinine. The amoeba again can respond only to changes in the composition of the fluid in its immediate vicinity. When multicellular organisms begin to specialize, this comparatively simple chemical adjustment is not found adequate and special methods have to be elaborated by which a ' colony ' type of life can be perpetuated. Individual cells of multicellular organisms begin to manufacture substances through which the different members of a cellular unit can be influenced. These substances or ' hormones ' circulate in the fluids of the body, and play an extensive rôle in *hormonic* adjustment to environment. Their primary purpose is to initiate automatic reactions and to sensitize the tissues to react either more rapidly or more slowly. The higher we ascend in the animal scale, the means by which the organism responds to environmental changes become more varied and complex, and an additional mechanism of adjustment other than chemical and hormonic is called for. For this purpose, the anatomically defined autonomic *nervous* system, both sympathetic and parasympathetic, has been developed. Finally, when the level is reached at which reason is developed, not only are accomplished changes appreciated but the possibility of alteration, made or threatened, can be recognized and guarded against; in other words, the adaptive reactions become conscious and adjustment to meet them, ' volitional '. Thus, among higher animals the distance receptors (eye, ear, nose) give warning of approaching danger, while in man complex mental processes allow the possibility of altered environment to be inferred, although the actual change may not be imminent. All the reactions of a biologic mechanism to environment may therefore be said to be mediated through three distinct but mutually related and integrated processes—*chemical, endocrinal* and *nervous.* The three components are functionally inseparable, and no one component can be disturbed without disturbing the others.

Reserve forces of the organism.

A living organism, whether a single cell or an integrated cell mass (the individual) may therefore be regarded as a highly unstable system, which tends to reproduce itself continuously under the average of conditions to which it is subject, but undergoes disintegration as a result of any variation from this average. The ability to maintain an equilibrium without the breakdown of the adaptive mechanism under adverse conditions determines the development of the individual and ultimately of the species. The greater the possibility of protective reaction the greater are the chances of survival. It seems important therefore to stress the fact that the animal body, although often compared with a man-made engine, differs fundamentally from the latter in that it has latent reserve forces capable of adjusting the animal to a new environment; in other words it possesses powers of adaptability. These forces call forth hypertrophy of glands and tissues in response to appropriate stimuli and even carry out repair of damaged parts. Sensibility or facility of response can be improved by frequent usage or 'training' as in the case of muscular exercise. The athlete can undertake a given amount of exercise with less disturbance of respiration and circulation than can the untrained person, and his return to the resting normal condition is also quicker. Unlike a test tube, in which chemical reactions are definitely limited, the efficiency of practically all the compensatory systems of the body can be increased by judicious use if the stimulus producing the reaction is adequate in each case.

THE INDIVIDUAL AND HIS ATMOSPHERIC ENVIRONMENT

The most important environmental factor is the atmosphere in which we live. Hippocrates, who may be called the father of the modern science of climatology, recognized the importance of 'airs' over 'waters' and 'places' and also appreciated the different qualities of the cold and the tropical atmospheres and other cosmic influences. As the atmospheric environment is so familiar, we fail to recognize the importance of the part it plays in moulding the physiology and sometimes the pathology of 'air-living' animals. We are likely to forget that we take in as much air by weight per day as we do of food.

The atmosphere or the air-mass surrounding the earth is not stable but fluctuates from place to place and from time to time, particularly with the 'cyclonic' waves. These fluctuations and atmospheric disturbances are normal and necessary sequences of temperature differences on the earth's surface. It is not my purpose here to examine these meteorological disturbances in detail. I only wish to draw your attention to the influences which such an unstable and ever-changing aerial environment exert on different phases of human activity—physical, mental, social, economic—and on racial development and retrogression.

Climate and climatic factors.

The term 'Climate' has been defined as the combined effects of the sun, the atmosphere and the earth upon living objects at any one place on the earth's surface. Climate primarily results from the effects on the earth's surface of the incident solar energy and its unequal distribution. For descriptive purposes, it is usually stated in terms which have reference to the so-called *climatic elements*—namely the temperature of the air, its humidity, also the amount of precipitation or rain, snow, frost, its motion, density, transparency and electrification. The climatic elements are dependent on physiographic factors, such as distribution of land and water, mountain ranges, nature of the soil, distance from the equator and height above the sea level. The latitude and the altitude are, however, the most important and deserve special attention.

Climate in the tropics.

It is generally assumed that the climates of the whole of the tropical zone are in all respects alike and therefore the term 'tropical climate' is often used, though incorrectly. Climatologists have divided the tropical belt into several sub-divisions according to the situation of the land in relation to the equator, the vicinity of water, the growth of vegetation, the presence of mountains or hills, the proximity of land to oceanic currents and trade winds, and its height above the sea level. All these factors will naturally influence the 'climatic type' of a locality. Thus the tropical zone includes deserts, damp forests, jungles, swamp lands and fertile islands refreshed by cool, steady winds from the ocean, low-lying plains and valleys under the influence of periodic oceanic monsoons, and mountains several thousand feet above sea level. All these regions are not equally disagreeable for the residents. The deserts, for example, are free from many tropical diseases, for their parched soil and dry, sterile air are unfavourable to the development and distribution of most micro-organisms and disease-bearing insects. On the other hand, the dust, heat and brilliant sunshine are very trying, and the paucity of water is obviously a serious limitation. Again, wherever mountains and plateaux occur in the tropics, the climatic conditions are distinctly different from the plain and may be actually mild and agreeable. It will therefore be seen that within the tropical zone, there may be areas with peculiar climatic types with their special advantages and disadvantages. In dealing with climate in the tropics, I shall confine myself to the consideration of its effects in tropical plains in the latitudes near the equator.

The climate in these regions varies but little and the temperature ranges between 75°F. (25°C.) to about 115°F. (46°C.). There are no seasons in the tropical zone and monthly and diurnal variations of temperature are slight. These areas are often subject to the influence of monsoons with their alternate dry and wet spells. They are usually very fertile and support a variety of luxuriant vegetation. The study of the climates prevailing in this zone has attracted most attention because these areas have been frequently colonized by the white race. A large portion of the plains of India have a climate of this type and therefore it is of very great interest to us to know the physiological adjustments required of human beings in such a climate.

Climate and the Individual

The influence of climate on man is so well recognized that it is often the main topic of daily conversation. One often hears of a 'bracing' climate or a 'relaxing' climate, and the beneficial effect of climatic variation finds its expression in our desire for a 'change of air'. Though we do not know whether and to what extent actual temperature, or humidity or wind affects human beings, there appears to be a direct relationship between the physical and mental vitality and the variability of climates. Huntington in his fascinating book on 'Civilization and Climate' puts forward the theory that all the world's great civilizations are now in regions experiencing often unexpected changes of weather and that the superiority of races inhabiting temperate regions of the globe is largely the result of climatic influences. Man is considered a mere creature of his meteorological environment and climate is said to rule the destinies of nations. Mills (1934–36) has corroborated some of Huntington's conclusions. According to him, there are energy differences between the races living in warm climates and those in temperate climes which cannot be accounted for on the basis of diet and mode of living alone. The tropical person has a lower oxygen consumption, a lower blood pressure and a lower capacity to meet emergencies than the resident of temperate zones. Some psychologists maintain that each climate tends to develop its own characteristic mentality. In other words, climate not only modifies the physical features but also the nervous system of the individual. These and other similar questions raise interesting issues which are not easily answered. Because of the difficulty involved in the study of the direct effects of climate on the individual, the data recorded in the literature are very discordant. There is a school of thought which maintain that too much stress is laid on climatic factors by Huntington and Mills and that many of their generalizations probably are not based on a rigidly scientific and critical evaluation of facts. While it is not possible in the present state of our knowledge to give any definite opinon, there appears to be little doubt that climate plays an important rôle, though often an indirect and subtle one, in the production of many physiological changes in the organism and as a predisposing cause or an accessory cause in many disease processes. I propose to examine some of these changes in the subsequent sections. It will suffice here to indicate that though man can live in any region where food and water can be obtained he can best develop his physical and mental capabilities under the most favourable environmental conditions. There seems but little doubt that there is also a distinct optimum condition for man, just as for plants and animals and any departure from it adversely affects the organism.

EFFECTS OF HEAT AND SUNLIGHT IN THE TROPICS

In considering the effects of residence in tropical climates, attention is at once directed to three major environmental factors, *viz.*, *temperature*, *humidity* and *sunlight*. There are a number of other climatic and environmental factors such as wind movement, atmospheric electricity, ionization, etc., which also affect the human organism, though the responses elicited do not leave lasting impressions on the individual. In nature, all these climatic factors operate simultaneously and the reactionary changes observed at any one time are in most cases a summation effect, one factor being superimposed on the other. Thus while the acute effects of encountering very high temperatures as of a heat wave or in a desert region may be tolerated without harm, the organism may show signs of intolerance or breakdown when excessive humidity is superimposed on such a high environmental temperature. This interdependence of several climatic factors makes the analysis of the effects of different components which constitute the 'climatic drive', a difficult matter and is mainly responsible for many of the conflicting views which have been expressed. Let us consider each of these factors separately and see to what extent each component contributes to produce the resultant total effects.

Sunlight.

The biological effect of sunlight has received perhaps more attention than any other factor in this group. A careful perusal of the literature has convinced me that the knowledge gained in this branch is indefinite and unsatisfactory. The beneficial results obtained by heliotherapy in tuberculosis and the effects of ultra-violet light in the treatment of rickets created the impression that the ultra-violet portion of the spectrum was the important factor responsible for the biological effects produced. Several investigators in the tropical belts of Australia, the Philippines and the Netherlands East Indies have adduced experimental evidence indicating that the ultra-violet light, being non-absorbable by the skin, is probably much less important than the infra-red and the visible-red end of the spectrum, which penetrate the superficial layers of the skin and are perceived by the organism as heat energy. Whatever direct effects tropical sunlight may have has therefore been attributed to its thermal action. Petersen (1936) has, however, shown that ultra-violet rays may produce physiological effects by first sensitizing the skin and then inducing a reflex stimulation of the thyroid and other glands of internal secretion. It is difficult in the present state of knowledge to evaluate the evidence with regard to the part played by the different components of the spectrum in producing physiological reactions in the individual.

Humidity.

The effect of humidity on the human organism has recently engaged the attention of public health authorities and sanitary engineers interested in environmental control through air-conditioning methods. That humidity modifies, to a great extent, the effects of heat is generally recognized. A moist humid atmosphere is associated with depression and discomfort and conversely, dry air, irrespective of its temperature, induces a feeling of comfort and well-being. The water content of the atmosphere must affect the water content of the body. In the regions of high environmental temperature such as are met with in the plains of India for example, greater humidity will prevent proper evaporation and heat loss with resulting disturbances in the respiratory exchange in the carbon dioxide content of the blood, and consequently in the water and ion balance. It may therefore be stated that high humidity, by diminishing evaporation of sweat merely aids in increasing the effects of heat, but as a direct factor it does not appear to possess any great specific importance.

Temperature.

Studies on the changes produced in the body of man as a result of exposure to high environmental temperature have been numerous, but, like most aspects of tropical physiology, the data are conflicting. It has been reported that a change in the environmental temperature produces a change in the *body temperature* of the individual and that in the tropics body temperature may be permanently above the average in the temperate zones. Though a large amount of work both in man and in experimental animals has since been published, the position is still undecided. While it is true that a change in the body temperature of an individual may be easily affected for brief periods by exposure to high external temperatures, it is doubtful if, in view of the sensitive heat-regulating mechanism in man, a permanent change can be brought about by prolonged exposure such as residence in the tropics. The same argument may be adduced against the contention of some workers that the *skin temperature* is raised in tropical zones. From physiological considerations, it is logical to assume that the flushing of the skin, as a result of exposure to a hot environment, raises the skin temperature, but the temperature soon drops when perspiration breaks out. It has also been suggested that darker coloured individuals in the tropics possess a higher skin temperature than the light coloured ones. This statement also has not been confirmed.

Regulation of body temperature.

The chief climatic factor affecting the individual in the tropics being the high environmental temperature, the adaptation that he is called upon to make is naturally one of heat regulation. This is accomplished by a fine balance between *heat production* and *heat dissipation*. Heat is always produced in the body by the metabolic activities of the protoplasm and, if life and the power of work of the individual are to be maintained, this heat production cannot be reduced below a certain minimum. Hence, heat regulation of the individual is more often effected through modifications of the various mechanisms available for heat loss, than through changes in heat production.

Heat loss and rôle of pigment.

It was generally recognized that tropical races are at an advantage over the European settlers in the matter of heat dissipation. The possibility suggested itself that acclimatization for generations in a climate where the mechanism of heat loss had to operate under excessive strain might have endowed the skin of the tropical races with an additional power and facility in getting rid of excess heat by the processes of physical heat regulation—conduction, convection, radiation and evaporation—at a more rapid rate than in individuals from cooler zones. It has been claimed that the skin of tropical races loses heat by convection more rapidly than the skin of white races but these conclusions have not been universally accepted. The suggestion next put forward was that the dark skin radiated heat quicker than the white skin, but satisfactory evidence has not been obtained in favour of this contention. It is therefore difficult to state with any degree of certainty whether the presence of pigment in the skin confers any real advantage so far as heat loss by *radiation* is concerned. There is however little doubt that pigment plays an important part in heat regulation by other channels. Owing to the high absorption coefficient of melanin, heat is rapidly produced in the skin; this stimulates the local heat receptors with consequent reflex sweating. Moreover, pigmentation of the skin is necessary to protect the deeper structures from the injurious effect of sunlight and to protect the sensitive cutaneous nerve endings from irritation. The brown-skinned races in the tropics, by virtue of the pigment, have apparently developed a more sensitive cutaneous heat-regulating mechanism, and they can cool off more rapidly by reason of the early formation of a fine layer of sweat drops. It is generally admitted that Europeans who tend to take on pigmentation are on the whole better acclimatized to the tropics than those who do not darken. The studies of Acton in the School of Tropical Medicine on the pigments of the normal skin of Europeans and Indians are of interest in this connection. He found that the pigments present in the basal cell layer of the epidermis of the two groups did not differ in the actual amount (quantity), but in their chemical composition (quality). The pigment present in the Indian skin was deeper brown in colour and showed a distinct tendency to increased chemical reaction with 'dopa-oxidase'. The significance of this is not yet clear. The precursor of melanin is dioxyphenylalanine which is again a breakdown product of the amino-acid, tyrosin. It is possible that the differences in the diet and metabolic rates in the natural tropical inhabitants might be ultimately associated with the production of a chemically distinct type of pigment in the skin. The distribution of pigment may also play a part in bringing about the adaptation which the tropical inhabitants are supposed to possess. Thus, in negroes, histological evidence shows that pigmentation is deeper and more diffusely spread than in the white races where the pigment is contained chiefly in the malpigian layer and in the superficial layers of the corium.

Sweat secretion.

For physical heat regulation, however, the activity of the sweat glands is of outstanding importance. Their efficiency depends on several factors: (1) humidity of the environmental air, (2) concentration of sweat glands per unit area, and (3) the degree of activity of these glands. Humidity, does not in actual practice exert a great influence, because apparently high degrees of humidity, provided they fall short of absolute saturation, can be borne by the system with impunity. The concentration of sweat glands in the skin may regulate the amount of perspiration, and it was believed by many early workers that the better heat-tolerance of the dark-skinned races was probably due to this factor. Though some investigators have reported a greater concentration of sweat glands per unit area of skin surface among them, these findings have not been corroborated. From the point of view of heat loss, increased concentration of sweat glands cannot be considered specially significant as the quantitative outpouring of sweat is less important than its distribution on the skin to form an even film which leads to rapid evaporation.

Composition of sweat.

A study of the composition of sweat produced in extreme dry heat shows that there is an adaptive response on the part of the organism and that the concentration of salt in sweat decreases after the first few days in the hot environment. To cite a concrete example, the amount of sweat produced with ordinary type of work in a climate such as that of Calcutta (95°–105°F. or 35°–41°C.) may be as much as 7 litres during the day. Assuming a sodium chloride concentration of 0·3 per cent., this means a loss of 22·5 gm. of salt. Man's daily intake of sodium chloride is 10 to 15 gm. and since the average normal excretion of salt in the urine is in the neighbourhood of 12 gm. in 24 hours, the degree to which muscular work in such a climate may deplete body chlorides is remarkable. If this depletion is not compensated, the normal acid-base equilibrium of the body fluids is apt to be seriously disturbed and heat cramps from loss of salt may supervene. It seems clear that some sort of adaptation takes place in normal healthy individuals. Little is known, however, of the nature of this adaptation, though it has been noted that all men sweat more readily as they get accustomed to exposure to heat. This increased 'ability to perspire' is known to be one of the few definite adaptations to high temperature and it is interesting to note that it is a case of 'controlled' rather than profuse wasteful sweating. The sweat secreted is said to contain an unusually low concentration of sodium chloride and this would appear to be an attempt at conservation of chlorides, as even on a high chloride intake their concentration remains low.

EFFECTS ON THE DIGESTIVE SYSTEM

Atonia and stasis.

It has frequently been observed by Europeans coming to the tropics that there is a definite impairment of appetite and a lessened desire for animal food. Though this may indicate a diminished power of digestion, it is probable that the disinclination for animal food may be an adaptive response to a lower caloric need in the tropics. There is also a tendency to an atonic condition of the gastro-intestinal tract, as evidenced by an increased tendency to stasis with resultant constipation and gaseous distension. This may be due to sedentary habits and lack of exercise though it is perhaps largely due to the fact that Europeans in the tropics are apt to follow their old dietary habits suited to temperate climates and do not take enough carbohydrates, vegetables and water to provide for the roughage. On the other hand, it is possible that the high environmental temperature in the tropics leads to a vaso-dilatation of the skin capillaries and a reflex vaso-constriction and anæmia of the splanchnic area, resulting in diminished gastric and biliary secretions and possibly also, in an atonic condition of the stomach and intestines. Muller and Petersen (1936) called attention to the fact that, with skin stimulation, the activity of the mucous membrane of the stomach and gastro-intestinal tract was decreased, but with lessened activity of the skin (as with cold) the functional activity of the mucous membrane of the gastro-intestinal tract was increased. It is probable that the inhabitants of warm climates make an appropriate physiological and dietetic accommodation by the greater use of condiments. Spices in solution are known to increase the activity of the villi and secretory glands, and the free use of condiments in the tropics may be an expression of the greater need for gastro-intestinal stimulation where skin activity is normally unduly accentuated.

Gastric acidity.

A general impression seems to prevail that gastric acidity of rice-eating Indians is lower than that of meat-eating Europeans. Napier and Das Gupta (1935) carried out a fractional gastric analysis on a number of normal Indian male and female subjects and found that on the whole their gastric acidity was higher than in normal Europeans. This is contrary to expectations, for hot climate and vegetarian diet are both believed to be factors that tend towards decreasing gastric acidity. No explanation of this phenomenon is yet forthcoming.

Bacterial flora.

Bacteriologists have claimed that the bacterial flora in the intestines of inhabitants in the tropics are different from those of colder climes. Arnold (1934) has shown that the bacterial flora of the lower intestinal tract vary with external temperatures and hence it is natural to expect a difference between those found in the tropics and the cooler regions. As the nature of the food is also known to influence the relative proportions of the various bacterial groups in the intestinal flora, and as the predominant dietary constituent in the tropical inhabitants is carbohydrate, the claim has much in its favour. Workers in this field appear to agree that an animal protein diet encourages the growth of proteolytic types, whereas the addition of lactose and dextrin stimulates the development of aciduric micro-organisms. Normally, a sufficient amount of lactose in most instances will cause a complete transformation of an ordinary mixed flora into one consisting predominantly of streptococcal and lactobacillary types. It has for instance, been recently shown that banana powder, apple powder, and raisins, when fed to white rats subsisting on a high protein diet, consisting exclusively of raw chopped beef, produce a change in the intestinal flora from one in which non-aciduric bacteria predominate to one in which *Lacto-bacillus acidophilus* is the outstanding organism. It has been further pointed out that the simplification of the intestinal flora varies directly with the hydrogen-ion-concentration, a *p*H of 7·0 being characteristic of a gas-producing proteolytic type, whereas an increasing acidity is characterized by a diminution of proteolytic types and the replacement by the aciduric types. It is evident, therefore, that a diet containing sufficient carbohydrate is capable of effecting a complete turnover from a heterogenous gram-negative type of flora in persons fed on high protein diet, to a flora markedly simplified and gram-positive, inducing coincidently a change in the hydrogen-ion-concentration from nearly neutral to distinctly acid.

Recent work (1937) on the hydrogen-ion-concentration of fæces of different classes of persons living in Calcutta shows that, whereas the reaction of the stools of most of the Bengalees is acid, those of the Europeans, Anglo-Indians and Marwaris is mostly alkaline. Although the Marwaris are vegetarians and live on a predominantly carbohydrate diet, they consume very little of rice and take more of wheaten bread (*chapati*). It would appear that the consumption of rice produces an acid reaction in the large intestine while wheat produces an alkaline reaction. When Bengalees were put on bread, and rice was cut off, the reaction of the stools changed from acid to alkaline in most cases. In view of the acidity of the stools, it was thought likely that aciduric organisms would predominate in the stools of Bengalees, but surprisingly enough *Lactobacillus acidophilus* could not be isolated.

With regard to bacterial flora in the normal intestinal canal of Indians and the differences, if any, that may exist in this direction between Indians and Europeans, our knowledge is far from complete. In an extensive survey of the bacterial flora carried out in the School of Tropical Medicine, a non-lactose fermenting gram-negative bacillus (*B. pseudocarolinus*) was frequently isolated from normal healthy individuals in Bengal. This organism is not present in the stools of Europeans who have never come to the tropics. It appears to have no definite relationship to the dysentery group of organisms excepting that it is sometimes lysable by dysentery phages. In this connection it is interesting to note that *Monilia psilosis* which according to Ashford (1924) is the causal organism in sprue is frequently found in Calcutta in the stools of persons, who are definitely not suffering from this disease. It is not possible in the present state of our knowledge, to state definitely whether such organisms are normal inhabitants of the intestine or whether they play any part in the causation of the disease.

EFFECTS ON THE RESPIRATORY AND CARDIO-VASCULAR SYSTEM

Frequency and depth of respiration.

There is good deal of divergence of opinion with regard to the effects of tropical climate on respiration. According to some, the frequency of respirations is decreased while others hold that it is increased before acclimatization. The consensus of opinion appears to be that the rate is diminished but the depth, as indicated by measurements of the minute volume, is increased. A slightly deeper breathing is more efficient for the individual, economizes energy and at the same time, the increase in the volume of air breathed cools the system. These changes in the rate and vital capacity are probably of a temporary nature, evident only in the case of the white immigrants to the tropics, and are not apparent in the natives of the tropics. Thus, it has been repeatedly shown that the respiration rate in the native residents of India, Java and the Philippines does not show significant changes as compared with the standards obtained in the cooler countries of the West.

Pulse rate, blood pressure and blood volume.

A slight decrease in the pulse rate and in systolic blood pressure are very common findings in the tropics. Mills (1936) has shown that people migrating from West Central Europe or Central North America to the tropics nearly always suffer a marked fall in blood pressure within a year or two, even though no debilitating disease or infection has occurred. Probably there is a slight decrease in blood pressure due to lowered vaso-motor tone and a general slowing of physiologic activity in the high environmental temperature in the tropics, but the changes are comparatively insignificant. The increase in sweating which is necessary in the tropics must require a constantly increased blood supply to the skin, and has been estimated to be as much as 50 times of the amount in temperate climes. The immediate result, if the total volume remains constant, would mean relative anæmia of the splanchnic region and the vital organs in the abdomen. To counteract such circulatory disturbances there is usually an increase in the total blood volume. Barcroft and his co-workers (1923), in an expedition from England to Peru found that the blood volume increased as the tropics were entered. The rise in blood volume was accompanied by a fall in hæmoglobin indicating that this was a simple dilution effect, blood plasma being drawn into the capillaries from the tissues. These results signify that the organism in the tropics, becomes at least temporarily 'wetter' and so is able to sweat more easily and plentifully.

Hæmatological standards.

The pale complexion of the white races migrating to the tropics has been frequently referred to as an indication of anæmia or 'thinness of blood'. Most authorities are of opinion, however, that a tropical climate *per se* does not produce true anæmia. Several workers in the Dutch East Indies including Eijkman (1924) found that the values for red blood cells and the hæmoglobin lay more or less within the same limits for the white sojourner and the native residents of the tropics. Dhar (1937) in Calcutta studied the normal hæmatological standards of a large number of Indian women and found that the average values for hæmoglobin, red cells, mean diameter of red cells and leucocytes are lower than the average figures reported in the European, American and Japanese literature for the same age groups. Indeed, the normal average hæmoglobin value which this worker obtained (11·47 gm.) for Indian women would be considered in Europe and America as bordering on anæmia. Napier and his co-workers (1937) at the School of Tropical Medicine, on the other hand, have not obtained any evidence that the hæmoglobin level in the Indians and in the healthy Europeans in India was low. In the healthy male Europeans the hæmoglobin was usually about 125 per cent. on the Haldane scale (17·2 gm. per 100 c.c. blood) and seldom below 120 per cent. (16·6 gm.). This is much higher than the 'normal' figure usually quoted for Europeans in Great Britain. In two series of normal healthy Indians consisting of 50 and 30 individuals the mean hæmoglobin contents were found to be 14·77 gm. and 15·70 gm. respectively. Sokhey (1932) in Bombay got a mean of 15·11 gm. in a large series. These figures are not materially different from the normal figures given for males in Great Britain and, if anything, are slightly higher than the standard figure of 14·5 gm. given by Price-Jones. With regard to the number of red cells, the average figures obtained in the Calcutta series were 5,533,000 and 5,362,000 and the mean of the Bombay series was 5,110,000. These figures are again above the classical 5,000,000. Even if the figure of 5,428,000 given by Price-Jones is considered as the normal mean count, the figures obtained in the Indian series are not much below normal and there is no reason to believe, that the size of the red cell differs from that in cooler climates and the colour index, volume and saturation indices are all in the neighbourhood of 100.

Most hæmatologists in the tropics appear to agree that the white blood cells are generally decreased though the change is not very great. As a rule the poly-nuclears have been found reduced and the Arneth count shifted to the left. This has been fully confirmed by workers in Iraq and by Dharmendra (1937) in Calcutta. Napier (1935–37) found that the number of leucocytes if it differed at all, was slightly lower than in temperate climates, but the eosinophile percentage was definitely higher. In 50 normal city-dwelling Indians who had no heavy helminth infections, the mean eosinophile percentage was nearly 7·0. Not only is the normal eosinophile count of the Indian high, but in disease the eosinophilia tends to attain a very much higher proportion than in the Europeans in temperate climates, *e.g.* 60 to 80 per cent. eosinophilia is not uncommon in asthma and other conditions.

It is not possible in the present state of our knowledge, to explain the significance of the different hæmatological responses observed in the tropical races. From the findings of Napier and workers in the West, it seems reasonable to conclude that, far from interfering with the functions of the erythropoietic organs, the tropical climate may actually exert some stimulating action on these organs. The possible bearing of the low average white cell count on the defensive mechanism against disease processes requires further investigation.

Biophysical and biochemical changes in blood.

There is little doubt that there is a more pronounced disturbance of water metabolism and water movement in the tropics than in temperate surroundings. This will naturally be reflected in the water content of the blood. A number of observers have attempted to throw light on this important aspect of tropical adaptation by measurement of blood chloride concentration. Sundstroem (1925) working in Australia found that the blood plasma was more concentrated than normal and richer in chloride content in a hot environment. As the formed elements of the blood actually became richer in water, it was probable that there was a shift of water from plasma to corpuscles. Barbour (1924-5) showed that there is considerable dilution of the blood prior to and accompanying the outbreak of sweat in hot and humid environment. This hæmodilution may be only temporary as the heat loss through evaporation may reach such proportions that the water in the red cells may be drawn upon to supply the water for perspiration. A slight alkalosis has been reported particularly in persons of sedentary habits which can be removed by water intake and muscular exercise.

The average concentration of serum proteins in the blood of Indians according to Chopra and Mukerji (1931) appears to be slightly lower than the accepted standard figures of Europeans, but the albumen-globulin ratio remains unchanged. The results with regard to non-protein nitrogen content are not conclusive. Since protein intake is likely to be low in the tropics, this will probably be slightly lower than normal. The lipoid constituents of the blood including cholesterol have generally shown lower values. Blood sugar apparently is not much affected by the climate though it was generally believed to be high in the tropics. In view of the common belief that the tropical climate tended to produce an increase in blood sugar, it was thought that diabetes was more common in the tropics. The studies of Mills (1930) have shown, however, that diabetes is more common in the temperate climes. Serum calcium is appreciably increased, probably as a result of excessive production of vitamin D from ergosterol due to the radiant energy of the tropical sun. Sundstroem reported a reduction of total phosphorus, but the finding has not been confirmed.

EFFECT ON THE NERVOUS SYSTEM

That hot environment actually disturbs the psychological reactions of the individual migrating to the tropics is generally admitted ; but it is doubtful if the climate alone is responsible. The climatic element along with a large number of other factors, *viz.*, social hygiene, isolation, sedentary habits, alcohol, etc. undoubtedly plays a part. There is, however, a physiological basis for the concept that the higher centres may be influenced by a series of stimuli from the peripheral sense organs and there is a theoretical possibility that the nerve cells in the brain might be exhausted or fatigued if the stimuli are of a type to which the nervous system is not ordinarily accustomed. There are many instances where a close correlation of a pathological nervous state can be made with changes in the climatic and meteorological factors. It is, for example, well known in epileptic colonies that the fit-incidence rises when the weather is close and sultry, and before and during storms. Migraine is likewise affected by the weather. Victims of chronic pain have a peculiar interest in the weather. Neuralgia, locomotor ataxia, and other painful diseases are always aggravated when it is damp, cold and windy. The weather may influence the course of chronic psychosis and unfavourable conditions may exaggerate pre-existing states of either depression or excitement.

Tropical irritability.

The intense heat and the bright sunlight of the tropics are the two factors which have been most commonly incriminated as agents in weakening the control of the higher centres over the lower and causing the so-called 'tropical irritability and neurasthenia'. Pediatricians in the tropics have often said that in children, memory, initiative and application become bad after the tenth year. It appears however that the measureable physiological disturbances are on the whole not very significant. It has so far not been possible by physiological, psychological and biochemical methods to furnish the desired evidence for altered functions of the nervous system. There may be, however, non-measurable and subtle nervous effects which may be of fundamental importance in the problem of acclimatization. Residents in the tropics are less prone to feel the depressing effects of a continuous high temperature and humidity, and the nervous effects observed among white settlers are conspicuous by their absence in the natives. There is probably no impairment of the higher psychical reactions and memory traces in the former as has been claimed for the white sojourners.

EFFECT ON THE ENDOCRINE SYSTEM AND GROWTH

It has often been observed that the endocrine glands may be disturbed in tropical climes. The association of increased metabolism, high energy level and higher incidence of metabolic diseases in a cooler climate and a sluggish metabolism, a low energy level, decreased resistance to infection and lower incidence of metabolic diseases in a tropical climate are generally recognized, and it is probable that all these factors are ultimately bound up with the question of the activity of the glands of internal secretion.

Thyroid-adrenal apparatus.

Much experimental data both physiological and pathological have been collected, indicating that the thyroid-adrenal apparatus may be affected in a hot environment. The defective heat regulation of patients suffering from myxœdema directed the attention of workers to the reaction of thyroidectomized animals to changes in temperature. In the thyroid glands of animals reared in a hot environment definite histological evidence of a diminished colloid content has been found. Cramer (1930) adduced evidence to indicate that the activity of this gland is diminished after experimental heat exposure for a certain length of time. So far as the suprarenal gland is concerned, a relationship between this gland and heat regulation has been established by showing that exposure to cold is a powerful stimulus to its functional activity. According to Mills (1929) definite disturbances of body function may result from too prolonged and severe moist heat due to hypofunction of adrenal glands.

That the thyroid-adrenal apparatus is concerned in the heat regulation of the body, is borne out by pathological evidence. Lesions of these glands are frequently accompanied by marked disturbance of heat regulation, and conversely disturbances of heat regulation as in fevers, frequently produce lesions in these glands. High temperatures are known to affect adrenalectomized animals more easily, and frequently they die in a temperature which is not serious for the control animals exposed for the same length of time. All these facts indicate that there is a lowered resistance to heat in adrenal insufficiency.

These facts enable us to speculate on the close inter-relationship that exists between heat regulation and the thyroid-adrenal system and which afford a physiological basis for the study of the fascinating problem of the influence of climate on man. It has often been noted that a warm, moist climate with little change from day to day is 'relaxing'. This might be the result of a failure to stimulate the thyroid-adrenal apparatus and through it the sympathetic system. Conversely, the cool variable climate, which is associated with increased activity and energy, probably provides a continued stimulus to these endocrine organs and the sympathetic. Mills (1932) considered that it is by whipping up the glands of internal secretion (especially the thyroid, adrenals and pancreas) that the human organism responds to weather stimulation. The same explanation may be applied to the relation between climate and health. Why is the resistance against certain bacterial infections such as tuberculosis, increased by a suitably cool, dry climate, and by measures such as open air treatment, hydrotherapy and the like ? Hitherto, it has been thought that such measures increase the metabolism. An increase in metabolism, however, can be induced by other means such as muscular exercise, but this is likely to do more harm than good. The answer to the question probably is that those measures are beneficial which stimulate the thyroid-adrenal apparatus without exhausting it and thus strengthen the normal reactions of defence of the organism against bacterial infections. Conversely a warm, moist, monotonous climate weakens resistance against infections, not because it reduces metabolism as many have thought, but on account of the continued absence of a stimulus to the thyroid-adrenal and the sympathetic apparatus.

Sex glands.

It has often been stated that girls in tropical and sub-tropical regions menstruate at a comparatively early age. It is also a well-known fact that women *marry and bear children earlier in warmer countries than in* cooler regions. These facts have led to the belief that the tropical climate induces premature sex maturity. There is, however, no direct proof of this as no reliable statistics are available. In India, various ages, ranging mostly between twelve and thirteen years, have been given for the onset of menstruation. These figures are probably derived from observations on the time of motherhood. The mean age for the beginning of menstruation is 15 to 16 years among the negroes on plantation in Jamaica and Barbados. Greater stimulation and earlier maturity of the sex glands has been observed in North American States where the climatic changes are more frequent and more severe throughout the year. Mills and Senior (1930) have collected data to show that human fertility, as indicated by the conception rate, depends on seasonal variations in the temperature. The maximum conception rate is always found when the mean monthly temperature is around 60°F (15·6°C.). Mean temperatures above 70°F (21·1°C.) and below 40°F (4·4°C.) produce a definite depression in conception rate. Ogle (1934) confirmed these observations by experiments on animals and showed that white mice subjected to warm humid environments exhibited a low fertility. These results would indicate a definite depression, instead of a climatic stimulation of the gonadal activity of the females in the hot and humid regions of the tropics.

BASAL METABOLISM IN THE TROPICS

The question of the influence of climate on the basal metabolism of the individual is an important subject and has received considerable attention during the last 3 or 4 decades. No satisfactory evaluation of the effect of the climate on metabolism, however, is possible even to-day, in view of the wide divergency in the results recorded. A review of the work carried out in tropical and subtropical regions in different parts of the world shows discordant results. Time will not permit me to make a detailed survey of the evidence presented by different workers but I will refer to the work carried out in India which is typical of that done elsewhere. Mukerjee (1926) experimenting on 15 Bengali medical students, found that the basal metabolic rate was on an average 9 per cent. lower than the European standard (Sanborn Standard). Sokhey (1927) found that in 15 out of 21 students, the basal metabolic rate was 10 to 23 per cent. lower than that of the Du Bois standard. This was further confirmed by Mason and Benedict (1931) who found the basal metabolism 16·9 per cent. below the Haris-Benedict standard or 17·2 per cent. below Aub-Du Bois standard. Mukerji and Gupta (1931) showed a decrease in the basal metabolic rate by 13·3 per cent. below the Du Bois standard. Krishnan and Vareed (1932) working in Madras found that the basal metabolic rate was 12 per cent. lower in man and 16 per cent. lower in women as compared to Du Bois standard. It is not yet agreed whether this lower metabolism is the result of the tropical heat (Rahman, 1936) or is produced by some dietetic or racial factor (Mason and Benedict, 1931). Bose (1934) carried out a large number of observations by the Sanborn technique at the School of Tropical Medicine and came to the conclusion that the basal metabolic rate of healthy normal Indians living mostly on a mixed diet does not differ materially from the accepted standards of Europeans and Americans.

Taking a general view of the whole problem, it would appear that the observations of the majority of the workers who studied metabolism in the tropics are in agreement that there is either a slight decrease or no significant difference in the basal heat production in people living in the tropics as compared with the inhabitants of the cold or temperate regions. It seems inconceivable that such a fundamental factor as basal metabolism should be affected by climate to any great extent any more than the body temperature. A very low or high basal metabolic rate reported in the literature is probably due to uncontrolled observations or possibly some fault in the technique employed.

DIET AND ADAPTION IN THE TROPICS

Protein and fat requirements.

Among all the demands which the body makes on its environment that for food is of outstanding importance, and it is to-day becoming well recognized that correct nutrition may profoundly affect the well-being and the social value of the individual. Considerable attention has therefore been directed to the adjustment of diet for different deficiency diseases and on the question as to how a well-balanced diet, containing all the proximate principles and other important constituents (vitamins, etc.) could be made available to the masses. Caloric value of food-stuffs which was at one time the basis of dietetic studies, is for the time being relegated to the background, and comparatively less attention is now being paid to their energy and heat-producing properties.

As pointed out before, the adaptation which man is called upon to make in the tropics is primarily one of heat regulation. The problem of diet is intimately connected with the problems of heat regulation, body temperature and metabolic rate, and any one of these factors cannot be considered without reference to the others. Though considerable work has been done on different aspects of dietetics, the question of the suitability or otherwise to the tropical climate of the common food-stuffs available in the tropics is not satisfactorily answered. Nature offers fat and protein in the arctic regions and carbohydrates at the equator, and man in these areas has always accepted them as his staple foods. The old idea that the diet which a race has adopted in a particular region is best suited for its needs has been refuted, in the light of modern research on ill-balanced dietaries and nutritional diseases in those areas. It is not yet clear as to what is the optimum or ideal to be aimed at with a view to effect a suitable adjustment to the climate.

The proportion of protein, fat and carbohydrate varies considerably in the diets of different races, depending largely on the type of food available and also upon the customs existing in particular localities. The prevailing diet of the masses in the tropics is derived largely from vegetable sources and carbohydrates generally predominate in it. Nearly a century ago, Chevers thought that the Hindu dietary with a very moderate quantity of animal food was the one most suited for a tropical climate. It will be of interest to examine how far the generalization of Chevers is justified.

Biological value of proteins.

The protein requirement of the tropical races has been the subject of intensive investigation and research by a large number of workers in India and other tropical countries, but no definite conclusions have yet been drawn. It has been pointed out that in many parts of the world those who consume a diet with high protein content have a better physique and are more virile than others of the same race who, for one reason or another, consume less protein. In the north of Italy, for instance, where the protein consumption is higher, the physique is better than in the south. The same statement has been made about India although here racial differences may have something to do with the differences. McCay said about a quarter of a century ago—'As we pass from the North-West region of the Punjab down the Gangetic plain to the coast of Bengal, there is gradual fall in the stature, body weight, stamina and the efficiency of the people. In accordance with this decline in many characteristics, there is an accompanying gradual fall in the nutritive value of the dietaries'. McCarrison working in South India confirmed the findings of McCay and concluded that there is a chronic protein starvation in the dietary of the Indians. Recent researches by Ackroyd and Wilson in this country have shown that the main deficiency in the diet is the lack of proteins of high biological value and certain salts, and this defect in the dietary, which can be easily corrected with small quantities of milk is responsible for the malnutrition and consequently the poor physique of the children. On the other hand, the fact cannot be overlooked that the meatless diet of some of the finest soldiers of the Indian army has a low protein content. There is already a considerable volume of opinion that the protein intake in the tropics should be less than in temperate climates and the Chittenden and Voit standards of protein quota may not be applicable to the Indian dietary. It is well known that protein food, by virtue of its specific dynamic action, generates a good deal of heat. The Eskimos who live in the arctic zone, consume large quantities of meat, sufficient to raise their metabolism over 50 per cent. which is an obvious practical advantage. Such a diet in the tropics would be considered unsatisfactory as it would throw an additional burden on the heat-regulating mechanism which is already over taxed. From this point of view a low protein vegetarian diet seems logical and advisable in the tropics. Recent researches tend to show that there are a number of important factors which deserve special attention in determining the minimum quantity of protein necessary to preserve nitrogenous equilibrium, *e.g.*, the particular protein the subject is accustomed to take and the ratio of the inorganic bases to inorganic acids available to or formed in the body of the subject. The coefficient of absorption also varies enormously in proteins of animal and vegetable origin. Inhabitants in the tropics usually obtain a large percentage of their protein requirement (70 to 80 per cent.) from vegetable sources while Europeans do not draw more than 25 per cent. from this source. Vegetable protein is said to have less 'biological' value than animal protein. It is futile to work out an allowance of say 80 gm. of protein per day, if a good portion of it is derived from vegetable sources with poor 'biological' value and it may not be assimilated. Then again, a food may show variation in the absorption of its protein content merely because of various methods of cooking. For instance, *dals* (lentils, commonly used in Indian dietary) if not properly cooked lose a lot of protein value. If they are simply boiled until soft, as is usually done and consumed, about 40 per cent. of the protein content is lost from non-absorption. If, on the other hand, they are mashed and cooked with special attention to the temperature and water content, the loss is not so great. This also applies to rice which is the staple article of diet over a large part of India. A diet, theoretically perfect, may still be quite unable to supply the physiological needs of the race for whom it is intended. It is therefore of utmost importance that in assessing the amount of protein in a diet, its source should be known and the computation for protein requirements made, with special reference to the manner in which it is going to be available for final consumption.

Fat-free dietary.

It is a common experience in the tropics to find that the poorest classes live on an almost fat-free diet. The very small amount of fat that they do eat is also often adulterated. Thus, mustard oil which is consumed by quite a large section of the population in Bengal is often impure and contains adulterants ; the palm oil of other tropical dietaries is very variable both in fat and vitamin content. That fat is an important constituent of diet has been long known but that it is also an essential constituent which cannot be replaced entirely for instance by carbohydrates was not realized before. Recent researches have forcibly stressed the fact that fats, if completely excluded from the diet, might lead not only to stunted growth but also to the development of various lesions indicative of malnutrition in the body. The fatty acids in fat are probably quite as important as the fat-soluble vitamins. From these considerations, it is logical to conclude that the almost fat-free diet of the Indian races is an important cause of the general and wide-spread malnutrition. From the point of view of adaptation to a tropical environment a diet comparatively poor in fat has obvious advantages. In the colder parts of the world, where harder physical work can be, and often is performed, a fairly high caloric intake is necessary and this cannot be supplied without including a generous proportion of fat. A caloric intake of a Canadian lumberman of 9,000 for example, could not be consumed as starch without putting too much strain on the demands of the alimentary canal. Fat is much less bulky than cereal foods and, bulk for bulk, is a much richer source of energy and heat. Besides in the tropics an unduly large layer of body fat external or internal is not so necessary as in the cooler regions, which naturally leads to a diminished demand for it in the dietary.

Carbohydrates in the dietary.

Carbohydrates have a definite and important effect on the physiological mechanism of the body. Numerous workers have noted that a change from a fat diet to a starch one involves considerable retention of water and *vice-versa.* Some of it is taken up by the stored glycogen and some as extra fluid in the extracellular and probably intracellular fluids. In other words, on a carbohydrate diet, an increased amount of water is available for evaporation and urine secretion in case of necessity. Moreover, carbohydrates are always the first to be metabolized and hence *pari passu* more motile fluid is available while they are being consumed. Experiments on rats on a fat-free diet have shown that these animals consume more water and excrete actually less urine than others with fat in their diet. More fluid appears to be eliminated by the lungs, under such conditions. Further, pulmonary ventilation is greater when carbohydrates are being burnt, owing to a larger output of carbon dioxide per calorie of heat than on a fat diet. This would increase the heat loss by evaporation of water from the lungs. These experiments are suggestive in view of Eijkman's (1924) observations in Java. He found that the Malayan is more economical (physiologically) in his water elimination than the European. Under identical conditions, a European lost 143 gm.

of water and a Malayan only 105 gm. of water by insensible perspiration in a given period. Contrary to expectation, the Malayan had also the smaller volume of urine, even though he had received extra water, while the European had been deprived of it during the observation. The European appears to waste water as liquid perspiration which does not therefore perform its physiological function—namely evaporation and heat loss. The problem therefore is how much of this adaptation is racial and how much of it is due to carbohydrate diet conserving the body fluids. The increased urine elimination of the European may have been due to his greater excretion of nitrogenous products which would be much less in the Malayan with his low protein diet. The Malayan, on the other hand, may consume more salt, which under certain circumstances promotes retention of water.

The considerations set forth above are particularly important if we are to construct a dietary suited to the climatic conditions of the tropics. Some medical men, obsessed by the idea that a good dietary must be rich in protein and fat, have advocated the wholesomeness of the protein-rich European dietary for the tropics, overlooking the fact that whole nations and working classes can develop satisfactorily and lead healthy and mentally productive lives on a diet which is almost equivalent, as far as caloric value is concerned, to the European diet but which is very poor in animal protein. It seems that dietary types like racial patterns cannot be laid down in rigid terms. The dental structure and alimentary canal of man are pre-eminently suited for a mixed diet and he is therefore probably capable of adapting himself to diets varying widely in their compositions. The determination of the minimal animal protein requirements is an interesting subject for future research and it is possible that these depend considerably on climatic considerations.

TROPICAL CLIMATE AND RESISTANCE TO INFECTION

We have so far considered the effect of tropical climate on the individual involving chemical, physiological and psychical reactions. It would be interesting now to examine whether these changes extend to the bacterial flora of the mucous membranes of the throat, respiratory passages, the gastro-intestinal tract and other parts of the body. It is possible that climatic factors not only influence the physiological forces of the organism but also affect the pabulum on which the bacteria vegetate without in any way affecting the bacteria themselves. This brings us to the question of environment and host resistance, the importance of which from the epidemiological point of view cannot be over-rated. It seems logical enough to expect, if we accept the evidence that has already been presented regarding the alteration of the chemical, hormonic and psychical status of the individual as a result of environmental changes, that localization of bacteria and other micro-organisms in the tissues is favoured by association with altered membrane permeability, vascular changes, metabolic alterations and ionic shifts. If these changes take place in the particular foci such as the throat and the mucous membrane of the gastro-intestinal tract, the host parasite relationship may be altered and clinical disorder may result.

Infections of the gastro-intestinal tract.

There are many recorded experiments as to the effect of temperature and humidity on the resistance to gastro-intestinal infection. Arnold and his colleagues (1927–29) studied in considerable detail the effect of high temperature, especially when associated with high humidity, on the gastroduodenal bactericidal mechanism of the dog. They showed that normal dogs exhibit a self-disinfecting power for ingested bacteria. If a living bacterial emulsion was administered by the mouth, these organisms could not be recovered from the cæcum in a viable state. When these dogs were placed in warm rooms (90–95°F. and humidity 90 per cent.) and treated in an identical manner, the bacteria ingested by mouth were passed on to the cæcum in a viable state, showing that the heat and humidity caused an interference with the bactericidal power of the dog. Again bacteria injected into the ventrally fixed duodenum of dogs placed in warm rooms soon appeared in the cæcum in large numbers. The same animals, handled in a like manner at ordinary room temperature, destroyed the bacteria before they reached the cæcum. Since in these experiments gastric acidity was excluded, one must assume that there was some other factor besides gastric acidity, or in other words, that the humid heat caused a change in the bacteriolytic action of the intestinal mucosa. In mice infected *per os* with the same dose of *Salmonella enteritidis* the fatality at a high temperature and high humidity was almost three times what would be at the same temperature but with low relative humidity.

These experiments show that high temperature associated with high humidity favoured the passage of infecting organisms across the gastro-duodenal barrier and increased the permeability of the intestine so that the bacteria could pass into the lymphatics, and finally reduced the defence of the animal to such an extent that the severity of the infection was enhanced. The fact should not be lost sight of that these experiments dealt with sudden changes of temperature and humidity. Had the experiments been conducted on animals acclimatized to a tropical climate, the results might have been different.

In attempting to correlate the experimental findings with clinical data, we are confronted with certain difficulties. It is known that enteric infections, dysenteries, diarrhœa, and colitis increase during the spring and summer months and diminish during the winter. This increase, which is often sharp and sudden, is partly ascribable to the sudden rise in the external temperature which probably inhibits the gastric secretions and allows either infectious organisms or irritating toxic substances to pass more readily into the lower intestinal tract. Furthermore, it would appear that at a high humid temperature the intestinal tract is also more sensitive to the irritating substances produced by the normal intestinal flora. Mills (1928) in China, called attention to gastro-intestinal disturbances, associated with nausea and vomiting, following a sudden elevation in temperature and humidity. Similar effects have often been observed in India and Egypt. A sudden change to a high, humid temperature may therefore facilitate infection, or give rise to non-specific irritation. It is possible that there are certain other factors such as seasonal changes in the vitamin content of food-stuffs which are responsible for the rise and fall of resistance.

Goldwasser and Kligler (1930) studied the character of the intestinal flora of normal individuals during different months of the year under the influence of the usual diet. The number of bacteria excreted by a normal person was variable. During winter, the number of bacteria was relatively high, and cocci and anærobic spore-formers predominated, while in spring there was a transformation with a fall in the bacterial content with the coli group preponderating and cocci and spore-formers diminishing. This indicates that, associated with the sudden rise in temperature, there are changes in the intestinal tract favouring the development of saprophytic and pathogenic members of the colon-typhoid group. The cumulative data go to show, therefore, a seasonal flux in the condition of the intestinal tract of man, while the experimental results obtained with animals show to a large extent that corresponding changes are induced in them by a change from an environment with a high to one of low cooling power.

Evidence of significant changes in the physiological condition of the nose and nasopharynx in response to changes in temperature and humidity has been produced and it may well be that some of the changes are associated with a lowering of local resistance and a predisposition to cold and other respiratory infections. Cock and Mills (1932) investigated the effects of atmospheric conditions on the upper respiratory tract and found evidence to indicate that it was not only the bacteria which were responsible for the catarrhal inflammation in the respiratory tract, but environmental factors such as seasonal alterations in temperature and humidity were also important accessory factors. External temperature and humidity were important controlling factors in the incidence and death rate of lobar pneumonia. In diseases like asthma, many workers in the field have recognized the influence of climatic variations and have more than once shown the association of climatic fluctuation with asthmatic attacks. Evidence has also accumulated which shows the seasonal fluctuations of streptococci in the throat and the severity of attacks of rheumatism and rheumatic arthritis. Wheeler, Wilson and Leask (1935) made observations on 4,857 throat cultures from 123 rheumatic children and have shown conclusively the close relationship of the pharyngeal flora with seasonal variations and the incidence of rheumatic attacks. Sharp and John (1937) have shown that carriage of hæmolytic streptococci is at a low level during the summer season and the warm climate of the Southern States of America tends to prevent or mitigate an attack of rheumatism. More information, however, is needed to prove direct correlation between environmental features and naturally occurring infections of the respiratory passages.

Radiation and resistance to infection.

It has been suggested that ultra-violet irradiation of the body, which is naturally obtainable in the tropics, has the power of increasing resistance to infections. A number of workers have demonstrated a temporary increase in the bactericidal power of the blood as the result of exposure to ultraviolet rays. This view is, however, not universally accepted. A careful study of the frequency of colds among irradiated and unirradiated groups of volunteers at Johns Hopkins Hospital has definitely shown that resistance to infection is not altered by irradiation. Similar results were obtained with rabbits injected with *Pasteurella lepiseptica*

Immunity reactions.

I do not propose here to enter into the field of immunity reactions and immune bodies in relationship to climatic changes. It is certain that the titre of immune bodies will change with the alterations in the physico-chemical status of the blood. The Report of the New York State Commission on Ventilation (1923) states that rabbits maintained at a temperature of 86°F (30°C.) showed distinctly delayed formation of hemolysins and reduced agglutinating power, as compared with control animals kept at 68°F (20°C.). It has been recently shown that in rabbits, heated so that their body temperature is raised to above 40°F (4·4°C.), agglutinins and bacteriolytic substances are produced in greater quantities than in control animals kept at room temperature. These preliminary studies indicate interesting inter-relationships and open up a new field of investigation.

Allergic manifestations.

A few words may be said about hypersensitiveness and allergy in the tropics as the phenomenon is closely associated with resistance to infection. The Indian tribes of America suffered much less from allergic diseases and were much less susceptible to experimental serum disease than the white races. Acton and Dharmendra (1933) pointed out the rarity of asthma of allergic origin amongst Indians. The reason for this lower incidence is not known and will remain unanswered until the true nature of allergy is known. There is evidence, both experimental and clinical, that hypo-adrenia plays an important rôle in the production of allergy. It has also been claimed that slight changes in the biochemical make-up of the body might give rise to profound changes in the reactions to foreign bodies and external stimuli. It has been shown, for example, that a shift of the hydrogen-ion-concentration to the alkaline side greatly increases sensitiveness in certain tissues. I have already indicated that hypo-adrenia might well be brought about as a result of tropical heat. If this hypothesis is accepted, a higher incidence of allergy in the tropics would be expected. Apparently such is not the case. This question must be thoroughly studied before any satisfactory explanation can be offered.

CONCLUDING REMARKS

From the survey of the effects produced by tropical environments on the physiology of the individual, certain points emerge which are worthy of further consideration and discussion. The idea that living bodies receive modifying impressions, both as regards form and quality, from the physical environment is of ancient origin and may be said to be definitely established by the experimental physiological data now available. There are, however, many lacunæ in our knowledge of the physiology of the external environment which need filling so that we may present a connected account of all these alterations in the functions of the human organism. The human organism (the microcosmos) swings in a definite rhythm with the macrocosmos (atmospheric environment). In the interplay of the meteorological rhythm with the biological rhythm of the individual, there may be synchronization, amplification, summation, or negation of effects, depending on the type and reactivity of the individual. It is conceivable, for example, that a long, thin, flaccid individual will react to an environmental feature such as atmospheric temperature, differently from a florid, stocky and strong type of individual. This brings us to the important question of ' constitution ' and shows how the question of normality may be inter-related ultimately to the constitutional types. For all practical purposes, however, it is not necessary to consider such individual fluctuations and peculiarities, as many of these variations are smoothed over and neutralized when larger groups are considered. It is therefore to standardize physiological data in terms of ' normal ' and ' normal ranges ' that we consider groups, and not individuals.

There is great need for determining such physiological normals in the tropics. Even in such simple matters as body temperature, blood pressure, etc., the findings are not always in accord. The question of a normal standard must necessarily be one for revision in the light of additional data and more exact technique. The differences of technique alone account for much of the difficulty in correlating earlier results on blood chemistry and blood pressure. When we are in a position to compare alterations produced in response to tropical environment, in terms of ' normals ' fixed in the tropics on ' tropical ' individuals, we will not only be able to understand and explain their significance more fully, but we may also be able to find out the optimum environmental conditions necessary in the tropics for the maximum development of physical and mental vigour. That environmental factors determine to a great extent the progress of mankind, Huntington has shown, and many of his conclusions have been confirmed by Mills.

The immediate effects of tropical heat and humidity on the inhabitants of cooler climates are known. Most of the physiological measurements have been recorded either on white races migrating to the tropics or at best on white settlers in the tropics. But these data cannot be used satisfactorily to explain how a native of the tropical climate would react to such variations. These records of altered physiological manifestations are no doubt useful indications of the type of variations to be expected, but any comparisons with the European figures as the standard will naturally be of doubtful value. Creditable attempts have been made by pioneer workers in the Philippines and Australia to supplement the information obtained on human races, by carefully controlled experiments on animals in artificially produced tropical environments. These animal experiments have supplied a large amount of useful data but these are also subject to the same criticism. The experiments were conducted for specified periods and though the results look quite conclusive as far as they go, they throw no light on how animals accustomed to tropical environments for generations would react to climatic changes. There is much scope for work of this kind in India with local strains of animals reared under conditions peculiar to the country.

The question of basal metabolism and the inter-related problem of optimum diet in the tropics needs further investigation even though the available data are by no means meagre. There seems to be some evidence to show that metabolism in the tropics is slightly lower than in cooler climates. As this observation fits in remarkably well with the known physiological facts regarding heat regulation in the tropics, and the diet in the tropics is predominantly rich in carbohydrates and poor in fats and proteins. European investigators are prone to lean to this view. Work in the Calcutta School of Tropical Medicine, however, has shown that there is hardly any difference in the basal metabolic rate in apparently healthy Indians (Bengalees) subsisting on an ordinary mixed diet. It is important, therefore, to re-investigate the problem and to see whether any racial factor is involved in it. Intimately associated with the question of basal metabolism is the question of the functional activity of the endocrines. There is some evidence to show that tropical environments depress the thyroid-adrenal apparatus as well as the gonads, and the sluggish metabolism, the lower energy rate, the earlier onset of the menopause and the supposed lowering of host resistance are only expressions of this endocrine dysfunction and inadequacy. Here lies an aspect of physiology which should attract young scientists. While some observations by histopathological and histochemical methods on the colloid content of the thyroid gland and the presence or absence of 'granules' in the cortex and medulla of the suprarenals have been recorded as evidence of their altered function, and while quite a large volume of work indicating the active participation of the supra-renal glands in the process of 'chilling' have emanated from the laboratories of Prof. Cannon of the Harvard University, there is as yet no definite and direct proof of this endocrine insufficiency or dysfunction under tropical environments. No satisfactory method exists for estimating the amount of adrenalin in the circulating blood and body fluids. If such a method can be devised and the technique perfected, it will be a distinct advance in the study of the activity of the endocrine functions in individuals living under different climatic environments, and in correlating this activity with increased or decreased metabolism, increased or decreased resistance to infections, increased or decreased somatic reflexes and psychical status of individuals. It has been reported that the incidence of metabolic diseases, *viz.* diabetes, exophthalmic goitre, and Addison's disease, pernicious anæmia, angina pectoris, chronic nephritis, etc. are lower in the tropics than in the temperate zones, while on the other hand, the infectious diseases generally are more common. It is also a general belief that sexual maturity is gained earlier in the tropics than in cooler climates. Recent researches, however, tend to indicate that the reverse is probably true. Much useful work could be done in this connection in India. It is probable that the final answer to these and to many such conflicting hypotheses will be found through a study of the endocrine inter-relationships. In presenting this subject, I realize more than anybody else, the complexities of the task and the limits of the undertaking that I have set upon myself. On going through the literature on the subject, one is forcibly struck with the extremes of opinion held and the disparities in the observed and recorded facts regarding the various responses of the body to climatic changes. The reason for these differences is not far to seek. The study of this aspect of physiology presents inherent difficulties, as here, unlike that of other problems one has to analyze carefully the innumerable possibilities entailed by the interaction of two highly dynamic systems, *viz.* the atmospheric environment with its constant fluctuations and 'pulsations' due to cyclonic circulation and temperature changes of the incident solar energy, on the one hand, and the human individual, that integrated cell mass in a state of dynamic equilibrium with his internal environment, on the other. The study of the physiological basis of the effect of climate on the individual shows that he is fashioning his own evolution by struggling to adapt himself to his climatic environment. This adjustment is brought about by three major components of the autonomic apparatus—chemical, hormonal and nervous. We have to study all these systems in all their various phases and ramifications, correlate all the disjointed observations in logical sequence and fit them into a perfect mosaic. Only then can we hope to project a picture, complete in all its details of the phenomena of biological adaptation of the organism to its environment, as exemplified in the process of acclimatization—individual or racial—of human beings in the tropics. In modern medicine and physiology, a consideration of the environmental influence has been relegated to the background for it has been thought that all acute infectious processes and normal physiological events run a comparatively steady course, uninfluenced by environmental factors. Enough scientific evidence is now available, some of which has been discussed already, which leaves little room for doubt that environmental factors are important forces to be reckoned with that if these are studied in greater detail, particularly with reference to the changes that they might produce in the human organism, a new branch of physiology may be developed in this country. The material is in abundance; but it needs the sickle of properly organized and directed research to garner a harvest which will be of the greatest value to us in India as well as to the world at large.

SECTION OF PSYCHOLOGY

President:—G. BOSE, D.Sc., M.B., F.N.I.

Presidential Address

AMBIVALENCE

NEGATIVISM

The mental phenomena which go by the name of negativism have been the subject of study by psychiatrists and psychologists for a long time past. Negativistic mental states are to be observed both in normal and abnormal persons. Young children very often show such traits. In normal adults also negativism is pretty commonly seen. It is however in certain types of dementia praecox that negativism attains a pathological development and becomes so prominent that it draws the attention of even the most superficial observer. These patients often do the exact opposite of what is demanded of them. In some instances it is possible to control them and make them follow a required course of action by asking them to do the opposite.

Negativism is to be noticed not only in the sphere of action but also in thought processes and affective manifestations. The same perception, for instance, evokes contradictory judgements and is invested with opposite feelings. Sometimes it is only the negative phase that becomes prominent and on other occasions a compromise between the opposing tendencies becomes manifest.

BLEULER'S CONCEPT OF AMBIVALENCE

No satisfactory explanation of negativism has yet been forthcoming. Bleuler in critically examining the views of Raggi and Paulhan (1887), Gross (1902), Lundborg (1902), Vogt (1903), Hoche (1904), Schüle (1904), Anton (1904), Alter (1904), Sante de Sanctis (1904), Dromard (1906), Kraepelin (1909) and others came to the conclusion that none of the theories offered by these different workers could satisfactorily meet the varied manifestations of negativism. Bleuler thought that the predisposing causes of negativistic phenomena are—

(1) ambitendency which sets free with every tendency a counter tendency,

(2) ambivalency which gives to the same idea two contrary feeling tones and invests the same thought simultaneously with both a positive and a negative character,

(3) an upsetting of the normal balance of these opposing and co-operating psychisms, and
(4) lack of clearness of logic in patient's thoughts.

Bleuler further believed that these patients live a life of phantasy and every influence acting from without is taken as an intolerable interruption to face which the negativistic attitude, which forms a component of ambivalence, is brought into prominence. The patient suffers from a sense of hurt which must be protected from contacts. The surroundings are looked upon as hostile by the patient. Bleuler said that sexuality with its ambivalent feeling tone is also often one of the roots of negativistic reaction and that " very pronounced phenomena of negativism affecting judgements and feelings have probably often other co-operating causes which we do not know " ; a conclusive explanation of all negativistic phenomena would be premature.

It seems that to explain negativism Bleuler conceived of an innate ambivalence in the human psyche. This ambivalence is something fundamental and cannot be further analysed. Bleuler stopped by merely stating that counter tendencies exist. He did not try to analyse their nature. What Bleuler meant by the two terms ambitendency and ambivalency is included at the present day in the single term ambivalence.

FREUD'S VIEWS ON AMBIVALENCE

Bleuler's concept of ambivalence, simple though it is, has thrown a flood of light on many obscure mental reactions. Ambivalence as a fundamental mental trait has been accepted by almost all psychiatrists and psycho-analysts. Freud utilized this concept in his psycho-analytic interpretations especially in elucidating the relationship between love and hate. Since the time of Bleuler he has been the only person to make an endeavour to probe deeper into the problem. Unfortunately Freud's analysis of ambivalence has not been very fruitful. He is sometimes inclined to consider ambivalence as a fundamental trait of mental life and sometimes he thinks that it may be a derivative of some other process. Freud writes ('Totem and Taboo', pp. 258), " We know nothing about the origin of this ambivalence. It may be assumed to be a fundamental phenomenon of our emotional life. But the other possibility seems to me to be worthy of consideration ; that ambivalence, originally foreign to our emotional life, was acquired by mankind from the father-complex, where psycho-analytic investigation of the individual today still reveals the strongest expression of it." Freud in his paper on 'Instincts and their Vicissitudes' suggested the theory that an instinct is built up by a successive welding of active and passive elements and that it is this that gives it the character of ambivalence. In the same paper Freud has discussed how an active phase of an instinct undergoes reversal into its opposite and is turned round upon the subject. The reversal affects not only activity and passivity, but also the emotional tone, or the content as Freud describes it, so that love is changed into hate. At one stage in this reversal, the original object of the instinct is abandoned and is replaced by the subject's self. This is made possible by the inherent narcissism of the ego and presumably the ego's tendency to identification. In his book 'Group Psychology and the Analysis of the Ego' Freud says, "Identification is ambivalent from the very first; it can turn into an expression of tenderness as easily as into a wish for some one's removal. It behaves like a derivative of the first oral phase of the organization of the libido in which the object that we long for and prize is assimilated by eating and is in that way annihilated as such." According to Freud the unconscious hostile feeling of the child towards the father is traceable to this mechanism.

The theory of superimposed opposite components of an instinct does not carry us very far. The main factor responsible for the ambivalence seen in introjection and identification is the functioning of the oral libido which from its very nature loves and destroys at the same time. Oral libido as a causative factor in ambivalence is the most important contribution of Freud in this line. The assumption that oral libido will explain all cases of ambivalence is not warranted by facts and Freud himself has never specifically maintained this proposition.

THE UNCONSCIOUS FACTOR IN AMBIVALENCE

There is an aspect of ambivalence which has not been properly stressed. Opposite types of behaviour under different situations or at different times are quite common among normal people and have never been sought to be explained by the theory of ambivalence; pure negativism would not call for a supposition of ambivalence either. It is only when opposite tendencies are observed working simultaneously and affecting behaviour that some explanation like that by ambivalence becomes necessary. A person who never listens to a command and does only the opposite of what is asked of him, is perhaps harbouring a feeling of defiance, but if such a person shows habitually a compromise reaction where both positive and negative traits are observable simultaneously, we are justified in bringing in the theory of ambivalence to explain his behaviour. A child may be loving its father today and hating him tomorrow quite consciously. Such alternation of behaviour is not necessarily an instance of ambivalence as we understand by that term. The child might have been chastised by the parent and the feeling of hostility might have been a temporary one and might be effaced by the kind behaviour of the father the next day.

Opposite tendencies and opposite feeling tones, it is true, cannot appear in consciousness together. There is however nothing to prevent them from emerging into consciousness alternately. Such alternation may be very rapid as for instance when a person is hesitating whether to do an act or not. Hesitation is not an ambivalent behaviour. In hesitation the conflict is in the conscious level. In true ambivalence, opposite tendencies are supposed to be present, but one of the contending elements at any particular moment must necessarily be unconscious. When a dementia praecox patient stretches out his hand to receive something and yet at the same time keeps his palm down and further shows no evidence of hostility or defiance, it is only then that ambivalence is supposed to be at work. Because of its unconscious element ambivalence is never a matter of direct observation ; it is to be regarded as an explanatory concept. It is true that under certain conditions the originally unconscious opposite tendency may come into consciousness. Under such circumstances it generally pushes its previous conscious counterpart into the unconscious so that ambivalence persists. I would therefore define ambivalence as a simultaneous working of opposite tendencies, one of which remains unconscious.

AMBIVALENCE IN FEELING, EMOTION AND JUDGEMENT

Besides expressing itself in opposite tendencies, ambivalence is manifested in connection with pleasantness and unpleasantness, in emotional states such as love and hate, and in opposite judgements. When we say that a child's attitude towards his father is ambivalent, we do not mean that he sometimes hates him and sometimes loves him, but that his behaviour towards his father is to be interpreted as a conscious love-reaction mixed up with an unconscious hate-reaction or *vice versa.* In such cases the conscious emotion attached to the act is either one of love or one of hate. It is usually assumed by psycho-analysts that the male child loves his father because of his affectionate behaviour and hates him because of his unconscious Oedipus rivalry. This hate, remaining unconscious affects the conscious love and makes the emotion ambivalent. It is further assumed that hate is as much an independent emotion as love and that its origin antedates that of love genetically.

The hate-reaction, as a psycho-analyst understands it, is an anomaly. Is there such a thing as an instinct of hate ? Freud in his paper on 'Instincts and their Vicissitudes' says, "We might at a pinch say of an instinct that it 'loves' the objects after which it strives for purposes of satisfaction, but to say that it 'hates' an object strikes us as odd." Freud assumes that hate is a reaction of the ego against painful surroundings. "The ego hates, abhors and pursues with intent to destroy all objects which are for it a source of painful feelings, without taking into account whether they mean to it frustration of sexual satisfaction or of gratification of the needs of self-preservation." On the other hand "Love originates in the capacity of the ego to satisfy some of its instincts auto-erotically through the obtaining of 'organ pleasure'." "It is primarily narcissistic, is then transferred to these objects which have been incorporated in the ego, now much extended and expresses the motor striving of the ego after these objects as sources of pleasure." The oral libido which loves and destroys at the same time is one of the earliest forms of love. Freud says, "This form and preliminary stage of love is hardly to be distinguished from hate in its behaviour towards the object. Only when the genital organization is established does love become the antithesis of hate." "The sexual and ego-instincts readily develop an antithesis which repeats that of love and hate." The ambivalence of love is to be traced to the admixture of hate derived from the self-preservative instincts. In the sadistic anal-erotic stage of libido development, the sexual function is governed by the ego-instincts to some extent. Thus hate and love get mixed up.

In his later writings, Freud has correlated hate and sadism with death-instinct which stands in contradistinction from love-instinct or Eros. The antithesis therefore, according to the newer view, exists not between self-preservative or ego and love-instincts, but between love and death instincts. I have not mentioned the rôle of death-instinct in ambivalence, because whatever I have said about Freud's older conception of the antithesis between ego and love-instincts, holds true *ipso facto* about death and love instincts. Freud has mixed up the emotion of hate with the desire to kill. Emotion and wish have both been invested with motive power for action. This idea of alliance of wish and emotion is at the root of the statement that there exists an antithesis between love and hate. Freud is thus led into an anomalous situation and has to admit that in the early stages of libido development "love is hardly to be distinguished from hate."

To ascribe ambivalence to love is therefore not a sound proposition. Of course, the question 'When does hate appear instead of love in a particular wish situation or *vice versa*' is a pertinent one. So also the problem of arousal of pleasantness and unpleasantness in an act. If we assumed wish to be the motive force of behaviour, it would be easy to prove that behind the emotional states of love and hate are wishes of opposite types, so that the real opposition between love and hate lies in the contents of the corresponding wish situations. I have also shown elsewhere that perceptions are determined by action attitudes, in fact the meaning of a perception lies in the action attitude it provokes, and an action attitude is to be interpreted as a latent wish, so that even in the domain of perception and judgement opposite tendencies may be discernible. Therefore if we assumed that ambivalence affects only the wish, it would be quite sufficient for our purpose. We would not discuss the opposition between love and hate as such in ambivalence but we must consider the opposition between the wishes that lie behind love and hate. We shall not be discussing the ambivalence in judgements, but the ambivalence that lies between the different action attitudes which determine those judgements and so on. The problem of ambivalence is therefore restricted to the domain of wish only. This restriction of connotation of the term ambivalence is not an arbitrary one, but is based on sound psychological principles. This would be the first step towards understanding the genesis of ambivalence. What I mean by the term wish and why I consider that wishes alone provide the motive force of our activities and that emotions and feelings, apart from their wish elements, are not to be held as incitors of actions I have discussed in a previous paper entitled 'A New Theory of Mental Life', Indian Journal of Psychology, Vol. VIII, Nos. 1, 2 and 3, 1933.

Let us probe deeper into the mechanism of the so-called opposition between love and hate. It is only in the domain of a dynamic entity that the concept of opposition holds good. If we are to recognize an opposition between such elements as pleasure and pain, love and hate, subject and object as has been done by Freud, we must suppose that these entities are of the dynamic order. As I have indicated before, whatever dynamism exists in these psychical entities, is to be traced to the action attitude in each. Pleasure and pain are opposites because they are usually associated with opposite types of reactions, otherwise they are just like any two different experiences, e.g., red and green colours. If we did not invest red and green with opposite action attitudes, we would not consider them to be opposites, they would be merely taken as different experiences. In the case of opposition between active and passive wishes, the opposite action attitudes are on the surface and need no analysis for appreciation. When we posit an opposition between love and hate, we fail to note that what we call love or hate are usually complex situations made up of wishes, feelings and emotions. Love-wish is not the same thing as love-emotion. The opposition is to be sought for in the domain of love-wish and hate-wish and not in love-emotion and hate-emotion or pleasure and pain.

For all analytical purposes, it will be desirable to separate the wish from its emotional and feeling attachments and to concentrate our attention on the dynamic factor only. What I have said here will be best understood by examples. The act of killing or destroying is often associated with the emotion of hate and it is quite easy to confuse the wish to destroy with the emotion of hate. If we remember that only wishes provide the motive force of action and that the emotions and feelings are more or less like epiphenomena then we shall avoid such pitfalls. I may destroy an attacking snake with the emotion of hate and throw it away with hate or disgust. Again, if I happen to be a head-hunter, I may kill my enemy with hate and preserve his skull with pleasure, or again I might kill a lamb with indifference or even pity and eat the flesh with pleasure. The act of destruction itself may also be pleasurable as for instance I may cut up a mango or dress meat with feelings of pleasure, sometimes almost with an emotion of love, and eat the mango or the meat also with love or pleasure. Freud made a jocose remark that the cannibal has a 'devouring love' for his enemy. Here the hostile act and the love act are identical and the wishes that lie behind these acts are the same. So the wish to destroy may be either a love-wish or a hate-wish and when such is the case one need not posit an opposition between love and hate.

Then again love and hate may show identical reaction-situations. In hate-situations the old Mosaic Law—'Eye for Eye, Tooth for Tooth'—holds good. The retaliation reverses the subject-object relation. In love reactions also the same sort of reversal of the subject-object relation takes place. A kiss evokes a counter-kiss just as a blow evokes a counter-blow. In the retaliatory reaction the predominant emotion tone is hate, whereas in love-reciprocity the emotion of love colours the reaction. There is no fundamental difference between the two types of reactions. In fact, one might with perfect justification say in certain situations, 'I would love to kill my enemy.' Revenge may certainly be sweet.

Similarly pleasure and pain are opposites only when they evoke opposite types of activities, otherwise they may be considered as two different experiences. The same act may be pleasurable today and painful tomorrow. A child would tear a living bird to pieces with great glee whereas an average adult would feel pain even in contemplating such an act. Just as there need not be an opposition between a love act and a hate act, so there need not be an opposition between a pleasurable act and a painful act. The arousal of pleasure or pain, love or hate depends on many factors. Feelings and emotions of any specific type are not inherent in specific acts. Neither can pleasurable and painful wishes nor love and hate wishes be listed under two separate classes. The same wish may be invested with either love or hate, pleasure or pain. So the antitheses between pleasure and pain and love and hate do not really exist. When an opposition is present at all it is traceable to different action attitudes and is independent of the affect.

IS AMBIVALENCE A CHARACTERISTIC OF A SINGLE WISH OR A PAIR OF OPPOSITE WISHES?

Since the opposition is to be noted only in the domain of wish, the genesis of ambivalence is to be looked for in the mechanism of opposition of wishes and the process by which one of the contending pair becomes unconscious. It would be wrong to speak of an ambivalent wish in the singular unless we considered that it is the same wish that is capable of being directed both towards the subject and towards the object, so that at one time the wish would be of the active type and at another it would be passive and again at one time it would be directed towards an external object in its effort at fulfilment and at another it will take up the self as its object. In fact this is the view that has been accepted by Freud and other psycho-analysts and from this standpoint the term ambivalent wish is not a misnomer. Masochism is according to this view nothing but sadism turned against the self. The wish in both the situations is the same.

If, however, we consider an active and a passive wish to be entirely different from each other, ambivalence should be traced to the opposition between the two and the preponderance of the one or the other in consciousness. Acting separately neither sadism nor masochism would be ambivalent, but the ambivalency is to be traced to their mutual conflict. It is the pair composed of sadism and masochism that shows ambivalence. The unconsciousness attached to one of the components of the ambivalent pair could very well be a matter for further psychological investigation and analysis just like the unconsciousness attached to a repressed wish. The difference between an unconscious repressed wish of the ordinary type and the unconscious component of the ambivalent pair need not be a fundamental one. Apparently, where ambivalence is concerned, the conscious behaviour would be exactly opposite to the repressed one, whereas in ordinary repression according to the usually accepted view, this is not necessarily so.

For a biologist who is not concerned with the mental attitudes of organisms and to whom all individuals of a species are more or less alike, there is no necessity of drawing a distinction between the subject and the object. When an animal bites another of the same species the biologist concentrates his interest on the act of biting. It is true that the activity of the aggressor and the passivity of the aggressed may draw his attention but he does not care whether the animal *A* attacks *B* or the animal *B* attacks *A*. The two situations appear identical to him for the purposes of his science. Thus he has no need to distinguish between such pairs of opposite wishes as sadism and masochism. He can with perfect justice say that there is only a single instinct in connection with the act of aggression and that it is not necessary to distinguish between the aggressor and the aggressed in the operations of the instinct of aggression. When an individual is playing the rôle of the aggressor, the instinct is directed towards the aggressed and when he is the aggressed party it is the same instinct directed towards him. There is no doubt that Freud's conception of sadism and masochism and his idea of the turning round and reversal of an instinct are more biological than psychological.

It must be noted that even in a passive wish situation there is an element of activity, e.g., in a love situation one actively desires to be kissed. Similarly, in masochism the subject actively wants certain situations of the passive type. The single instinct of aggression will not explain the desire to be aggressed which is the special characteristic of masochism. From the psychological standpoint, therefore, we are bound to assume the existence of distinct and separate active and passive wishes, in situations like those of sadism and masochism. No amount of sadism directed against the self will make it masochism until the individual willingly submits to the aggression. Directly he does so, we are bound to assume an independent passive wish wanting to be fulfilled under definite conditions.

One may submit unwillingly to a painful situation as a matter of necessity but this is not the same thing as the desire to be aggressed. Further, the theory of reversal of instincts cuts both ways so that instead of looking upon sadism as primary and masochism as sadism directed against the self, we might say that masochism is primary and sadism is only masochism transferred to the object. It is to meet such objections that Freud had to assume successive layers of active and passive wishes in the make-up of an instinct. Introspective evidence will fully bear out the fact that such active and passive wishes, although related to one another in certain ways, are quite independent by themselves and there is no reason to suppose that the one group is more important than the other. Pathological manifestations and psycho-analytic evidence are also in favour of the separate and independent existence of active and passive wishes. In fact, in his later writings Freud had to modify his views and assume a primary masochism (Freud—Collected Papers—Vol. II, pp. 255–268; 'The Economic problem in Masochism. Beyond the Pleasure Principle', p. 70) It is thus seen that neither the theory of admixture of eros and death instinct nor the theory of the turning round and reversal of an instinct really explains ambivalence. So long as we are forced to admit the independence of active and passive wishes and so long as we are not in a position to show the relationship between the contending elements we shall not make any advance on the theory of ambivalence put forward by Bleuler.

ACTIVE AND PASSIVE WISHES

The human mind is capable of developing both active and passive wishes. The desire to kiss and the desire to be kissed may both be experienced by a subject and both the acts may be pleasurable. There is no reason to suppose that the active wish gives more pleasure than the passive one or *vice versa*. Some of the active and passive wishes can be arranged in pairs of opposites, e.g., the desire to kiss and be kissed; pay and expect a visit and so on. It will be noticed that such pairs of opposite wishes are to be found mostly in the domain of love and social life, *i.e.*, where we have dealings with other sentient fellow beings. In connection with inanimate objects, corresponding active and passive wishes are not observed, e.g., the desire to eat a mango may be present but not its passive counterpart, *viz.*, the desire to be eaten by a mango. In fact the passive counterpart is something impossible of attainment here. The desire to kill a tiger has as its passive counterpart the desire to be killed by the tiger. The possibility of the event corresponding to this type of passive desire is present. Tigers do kill men but one never comes across the desire to be killed by a tiger in actual life except perhaps in a suicide who chooses this particular mode of ending his existence. Under ordinary conditions this passive situation appears in consciousness not as a desire to be killed but as a fear of being killed. I shall have to say something more about paired wishes presently.

SUBJECT-OBJECT ANTITHESIS

Neither the antithesis between love and hate nor that between activity and passivity gives us any clue to the solution of ambivalence. I shall now take up the question of subject-object antithesis. The polarity of subject and object has been an eternal problem with the philosophers. Leaving all philosophical speculations aside, I shall try to analyse the subject-object relationship from the psychological standpoint. It will be advantageous at this stage to limit ourselves to wish situations where the object is a sentient and reciprocating individual. Let us suppose that *A* feels a wish to make a monetary gift to *B* who is willing to accept it. Such a wish situation demands that *A* must have some conception of *B*'s needs before the desire to help him arises in his mind. When we realize the sufferings or exaltation or in fact any other characteristic of another person, we unconsciously place ourselves in his position. It is thus by the mechanism of identity that *A* is able to realize *B*'s position. In identity a part of the ego is thrown out as it were and gets itself attached to the object. It is by means of this bond that we appreciate that the person is desirous of receiving some help. Identity enables us to divine the wishes of a sentient being who is similar to us. In the wish situation under discussion the portion of the ego that is thrown out and is able to effect identification, feels like the object, *i.e.*, it wants to receive something through the object. We may call this portion of the ego the objective half of the ego or simply the objective ego. It is really a portion of the original ego. The original ego splits up into two. The portion which feels the subjective wish, *i.e.*, the desire to make a gift, in the illustration under consideration, may be termed the subjective half in contradistinction to that part which effects the identification and in a way feels the wishes of the object and which I have just termed the objective half. It will be noticed that the subjective ego feels the desire to make a gift whereas the objective half feels the desire to receive the gift. This latter wish remains more or less unconscious and is foisted off on the object who is looked upon as a person willing to receive a gift. To make a gift and to receive a gift are quite opposite tendencies and it may be assumed that the original ego in coming into contact with an object and in trying to realize its characteristics, splits up into a subjective and an objective half, one of which feels the stress of an active wish and the other that of a passive one. The active and the passive wish form a pair just like sadism and masochism in ambivalence. The resemblance goes further. Just as in ambivalence one of the components of the pair is unconscious so here also the objective half of the ego acts in an unconscious manner.

SECONDARY EGO

To ascribe a wish to the projected objective ego is not a mere theoretical necessity. Under certain situations, objective wishes may be consciously felt as for instance in empathy. In Vaishnav literature, one comes across an interesting episode regarding Radha, the consort of Krishna. Radha feels bitterly the absence of Krishna for some time and then imagines herself to be Krishna seeking Radha. Certain paraphrenics complain of the curious symptom that directly they come into contact with any object and want to grasp the nature of it, the feeling comes to them that they are one with the object, so that the contemplated action becomes an impossibility and they want to have the exact reverse done to them. One of my patients told me that whenever he wanted to bow down before the God Siva, he became Siva himself and demanded homage. Sitting opposite to me during the analytical hour he would often ask me to give him my associations. When questioned about the strange behaviour, he said that whenever he tried to concentrate on what I was saying, he felt that the situation was reversed and that he was the doctor and I the patient. It would appear that in such cases, the original ego transferred itself to the site of the object and behaved as a secondary ego from the standpoint of the original object and felt the objective cravings consciously; the striving of the original subjective half became unconscious.

We might push the analysis a little bit further. In the gift illustration there is no disturbance of the contemplated action, whereas in the case of Radha and in that of the paraphrenic patient, the originally contemplated act is disturbed. It thus seems that under certain conditions, the unconscious wish belonging to the objective ego sets up an opposition against its subjective counterpart and in becoming conscious as a secondary ego pushes its antagonist into the unconscious level. It then sways the original ego and makes it behave according to its dictates reversing the original subject-object relation. There is an inherent opposition between the subjective and objective halves of the ego. This opposition is the psychological prototype of the eternal antithesis between the subject and the object. It is a fundamental opposition and includes within it the opposition between activity and passivity. In fact, it is the most perfect opposition conceivable. Mere turning round does not explain this opposition or reversal nor does subsequent choice of a new object by the primary ego as has been supposed by Freud. We must assume a secondary ego taking up the position of the original object and pairs of opposite wishes in the original ego corresponding to the subject-object relationship before we could explain the curious behaviour of Radha and the paraphrenic and the change from sadism to masochism.

OPPOSITE WISHES

In view of the perfect opposition existing between the subjective and the objective halves of the ego, it is a wonder that a wish situation comes to be fulfilled at all. As a matter of fact in unimpeded actions, the objective ego's wish is not consciously realized and is not felt as the subject's striving. As I have already said it is foisted into the object and serves to bring the position of the object prominently before the ego. The subjective striving is satisfied directly whereas its objective counterpart finds unconscious gratification in the realization of the object's position during the act. Hence all conflict is avoided and the entire action is invested with a pleasurable tone.

We might assume that pairs of active and passive wishes of all sorts exist in the psyche ; the component wishes forming each pair are exact counterparts of each other, *i.e.*, they correspond to the specific subject-object situations. Ordinarily the wishes inhibit each other and the ego remains in a neutral state free from apparent strain. Under certain conditions, in the presence of an object, the ego's equilibrium is disturbed and the wish corresponding to the objective situation is thrown out by the ego as a pseudopodium, to borrow a biological analogy, and it invests the object. The subjective counterpart of the wish is felt by the ego as a striving towards the object. When the act is completed, the subjective striving finds satisfaction at the situation of the main ego and the objective striving at the situation of the object carried there, so to say, by the pseudopodium. Sometimes, as for instance in the case of the paraphrenic mentioned before, it seems as if the pseudopodium became the principal ego and the striving in that situation is felt as a conscious wish. This is the process of the formation of what I have described before as the secondary ego. Whenever the ego thinks in terms of the object, it may be described to be functioning as the secondary ego, the primary situation being then treated as a secondary object situation. This is complete reversal of the original situation.

In dealing with inanimate objects the objective striving is seldom felt as a conscious wish. Hence in situations where no reciprocity is possible we do not usually notice the formation of a pair of opposite wishes. In paraphrenics the objective striving, even with inanimate objects, is sometimes apparent. My patient said that when he came before a tree, he became the tree himself. This delusion is really a manifestation of the wish to become a tree. Opposite pairs of wishes may therefore be supposed to exist in all possible wish situations. It is only where reciprocity is possible that the components of the pair become manifest sometimes as an active and sometimes as a passive wish. When the objective half of the ego can transfer itself without impediment to an external object, there is no struggle and the conscious subjective striving becomes a pleasant one. When, however, the transference of the objective half is not perfect, struggle within the psyche is inevitable during the fulfilment of the subjective conscious wish and the act becomes painful. It is under such circumstances that hate, disgust, pain and other unpleasant experiences arise and ambivalence develops.

REPRESSION

My view is that if there is an one-sided influence in childhood favouring the satisfaction of only one of the pair of opposite wishes, repression results ; if for instance a child is constantly allowed to have its own way in everything and is never made to feel any restraint, its sadistic wishes will have more opportunities for actual satisfaction than its masochistic ones. The 'channels' for sadistic discharge will develop at the expense of the masochistic outlet so that after a time, the accumulated tension of latent masochism becomes a disturbing factor and its channel of discharge being ill-developed, its mobility suffers. In a sadistic act the objective half of the ego plays the masochistic rôle. If the masochistic objective half is ill-developed and cannot be transferred to the objective situation, the sadistic act itself loses its pleasurable tone and shows signs of masochistic compromise or in other words ambivalence develops. It is repressed masochism that makes sadism ambivalent and *vice versa*. So with all other pairs of opposite wishes. The rôle of the opposite wish with an ill-developed channel of discharge is the same as that of any other repressed wish. My idea is that the prime force of repression of any wish is derived from its opposite counterpart. Sadism represses masochism and *vice versa*; active homosexuality represses passive homosexuality and *vice versa*; the desire to play the mother's sexual rôle represses the child's Oedipus cravings and so on. I have discussed the whole question of repression in detail elsewhere ('Concept of Repression and New Theory of Mental Life') and need not go into it again.

PAIRED WISHES

We may now revert to the question of opposition in paired wishes. From the standpoint of action attitude wishes may be broadly classed under two heads, *viz.*, active and passive. If we examine the nature of active and passive wishes with reference to their object choice we find, as I have already pointed out before, that some of them correspond to one another in a very striking way, e.g., the active wish to kiss a loved person has its exact counterpart in the passive wish to be kissed by that person. In the two situations the subject-object relations stand reversed. Such corresponding active and passive wishes are related to each other in certain definite ways. The action attitudes of two such corresponding wishes being exact opposites they cannot obviously arise in consciousness simultaneously. The verbal expressions corresponding to the two opposite action attitudes however, when divested of their cathexis, may both be conscious at the same time. There is a regular sequence of arousals of these opposite wishes. The satisfaction of one invariably gives rise to the conscious demand for the other. In kissing we expect to be kissed in return and in being kissed we return the kiss. Unless both the active and passive acts are gone through a feeling of incompleteness and tension persists. This is traceable to the operations of the unsatisfied wish. Such corresponding active and passive wishes are thus seen to be more or less inseparable and to form pairs. We might say that satisfaction, whether voluntary or involuntary, of one of the pair serves as a stimulus to the arousal of the other in consciousness. Such pairs of active and passive wishes are, as I have already mentioned, generally to be found in our dealings with other sentient individuals of our own species, *i.e.*, in love and social intercourse.

If, instead of confining our attention to the subject only in such wish situations, we take into consideration the reactions of the sentient object also we find that they follow a certain definite law. The same active and passive wishes of the pair that we find in the subject are in operation here also but with a reversed sequence. In being kissed the object also returns the kiss and in being asked to kiss expects a return kiss. It is thus that a kiss evokes a counter-kiss, a blow evokes a counter-blow. This is the mechanism of all reciprocal and retaliatory actions. The law that governs such actions is the Mosaic Law,

IDENTIFICATION

The presence of such opposite pairs of wishes both in the subject and in the sentient object leads to the formation of a special bond between them. The subject can easily appreciate the position and behaviour of the object in an act of this type. During kissing for instance the subject's desire to be kissed remains latent and it is this latent desire that enables him to realize the position and characteristics of the object who is also invested with the same desire. The subject's latent counter-wish is supposed to be the conscious wish of the reciprocating object. To revert to my previous description it is the objective half of the ego that feels the latent counter-wish and this is the bond of identification of the main ego with the object. Once the bond of connection is established the ego can transfer itself in its entirety to the object's position and behave as a secondary ego. In the first stage of identification, *i.e.*, when the objective half of the ego only is transferred to the position of the object the latter's willing participation in the act is realized; the subject knows that the object feels pleasure in being kissed. At the next stage when the secondary ego is formed, *i.e.*, when the entire ego can completely go over to the object's position the subject appreciates the latter's reciprocating tendency; there is complete identification. If the subject's original rôle is passive, as in early infancy, reciprocating reaction is the first to be established. In being kissed the child returns the kiss without having any sympathetic understanding of the object. This phenomenon is what I have designated elsewhere as action identity. Action identity is the basis of imitation. Action identity enables the child to realize the position of the active object and this is the bond which the developing secondary ego of the child utilizes to go over to the position of the object and effect complete identification or ego-identity as I have called it.

Under normal conditions the functioning of the secondary ego goes on more or less unconsciously and it is through this process that the ego expands and acquires fresh knowledge of men and things. The secondary ego may under exceptional conditions become fully conscious and can replace the primary ego as in the case of the paraphrenic mentioned before. In self-punishment and similar acts the secondary ego acts as the subject. It derives its motive force from the latent counter-wish of the primary ego.

THE WISH CIRCUIT

To explain reciprocal and retaliatory actions in the adult we have to assume ready formed pairs of opposite active and passive wishes within the psyche. These contradictory wishes inhibit each other and a state of equilibrium is maintained.

Under certain conditions which I need not discuss here one of the pair becomes prominent and appears as a conscious wish with reference to a special object. As soon as this conscious element of the pair finds satisfaction its inhibiting force is removed and its opposite counterpart springs to consciousness as an urge for a reciprocal or retaliatory act directed against the object. In all actions where opposite pairs of wishes come into play and where there is no repression the latent element of the pair throws out the bond of identification with the object making it possible for the entire ego to traverse this bond as a secondary ego and to establish itself at the objective point of the wish situation or the wish circuit as I have called it. A complete wish situation of this type therefore carries with it two pairs of opposite action attitudes, one at the subjective point and the other at the objective end. To come to our illustration, at the subjective end the conscious or the subjective half of the ego feels the active striving to kiss; at this point the objective half of the ego has the latent desire to be kissed. In establishing itself at the objective end the secondary ego looks at the original subject as the object for its strivings. The subject thus becomes the secondary object with reference to the secondary ego. The secondary ego also feels the urge of a pair of opposite wishes like the primary ego with this difference that its subjective half has a passive desire to be kissed by the original subject and its objective half has the wish to kiss him actively. This last wish is really the determinant of the reciprocal action on the part of the real object. If we name the subject and the object *A* and *B* respectively and if we assume that all the situations in the wish circuit are conscious we may summarize by saying that at the primary subjective position *A* feels the active desire to kiss *B*, at the secondary subjective situation *A* feels that *B* has the passive desire to be kissed by *A*, at the secondary objective situation *A* feels that *B* has the desire to kiss *A* actively and lastly at the primary objective situation *A* feels the desire to be kissed by *B*.

At the secondary subjective situation there is partial identity of the subject with the object, at the secondary objective situation the identity is complete; the subject has projected himself completely into the object's position and at the primary objective situation there is a complete reversal, in the Freudian sense, of the original craving. Ordinarily only the primary subjective position is conscious but the normal person can realize all the different situations of the wish circuit if he wants to. Under special conditions of repression any of these four situations may become prominent in consciousness to the detriment of the others. When the primary subjective position is conscious, *viz.*, *A*'s wish to kiss *B* in our example, it is considered a normal wish if there is some sort of realization of the other three situations. Where there is no such realization *A*'s wish is considered to be a selfish one as consideration for the other party *B*, who is the object, is lacking. When the secondary subjective position only is conscious, *i.e.*, when *A* thinks that *B* wants to be kissed by him the behaviour is an abnormal one ; here *A* wants to shift the responsibility of his own action to *B* ; it is akin to the plea—'the woman tempted me'. When the secondary objective phase only is conscious, *i.e.*, when *A* feels that *B* wants to kiss him the situation is exactly like that of paranoic projection. Lastly, when the primary objective phase only is conscious, *i.e.*, when *A* feels that he wants to be kissed by *B* the situation corresponds to the complete reversal of the original wish. It is like the conversion of sadism into masochism. All the three subsequent situations in the wish circuit are repression products and invariably show signs of conflict with the original primary subjective situation. The conflict is most acute between the first and the fourth phases, *i.e.*, the desire to kiss *B* and the desire to be kissed by *B*. Whenever there is any conflict the pleasure that should normally arise in the fulfilment of a wish is impaired either partially or completely and in its place pain and unpleasant affects make their appearance. For instance, if there is no repression both sadism and masochism become fully pleasurable acts. It is only when one opposes the other and the mobility of the secondary ego is impaired that sadism and masochism show signs of pain and compromise. Sadism becomes tinged with the unpleasant emotion of hate and masochism with the feeling of pain. Without repression there would be no such pain in masochism. A masochist does not crave for pain. Pleasure in pain is an impossibility. The masochist wants to enjoy certain passive situations and the concomitant pain is not his aim. It is an unavoidable evil to him. A perfect masochist would feel pure pleasure even in being crushed to death. That such individuals are not found is only a proof of the difficulty of avoiding repression where momentous questions like a matter of life and death are concerned. As a death wish cannot be repeatedly indulged in the channel for its discharge is never sufficiently developed to overcome repression.

CONCLUSION

Ambivalence is not a fundamental trait of mental life, but pairs of opposite wishes are certainly fundamental. The components of such pairs of wishes may have alternate complete satisfaction in reciprocal acts and partial satisfaction with unpleasant emotion tones in retaliatory acts. They may not necessarily produce ambivalent states and even when they do, in a large majority of cases the ambivalence is removable, showing that it is a repression product. Opposite types of behaviour corresponding to reversal of subject-object relationship are not necessarily ambivalent behaviour ; on the other hand they are to be considered a proof of the existence of opposite types of wishes.

To sum up, my contention is that pairs of opposite wishes are to be found not only in love and social intercourse but also in our dealings with inanimate objects. There is no wish without its opposite counterpart. Where the object is inanimate and the wish act is not reversible the opposite counter-wish seldom goes beyond the stage of latency. The latent counterpart helps us to appreciate the characteristics of the object. In paraphrenics, in whom words or verbal images take the place of things, reversal of a wish situation even with an inanimate object may occur; my patient said he became a tree when he looked at one. In reversible acts, *i.e.*, where reciprocity is possible, both the opposite wishes can dawn upon consciousness. If the opportunities for satisfaction for one is greater than those of the other a conflict is set up within the psyche and repression results. One of the elements of the pair then tends to become unconscious. It is the opposite wish that provides the prime motive force for repression; all other factors are secondary. The primary conflict is between opposite wishes. Antitheses such as love and hate, pleasure and pain, etc., are traceable to it. Love and pleasure are the primary affects. Hate, disgust, shame, anger, pain are all repression products. Identification, projection, introjection, turning round and reversal of an instinct, ambivalence, conscience, moral values, sense of social propriety, etc. are best explained by the assumption of opposite wishes producing conflict at different points of the wish circuit.

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